

# CORROSION AND HEAT RESISTING STEELS



CRUCIBLE STEEL COMPANY  
OF AMERICA  
NEW YORK CITY

A.M. CASTLE & CO.  
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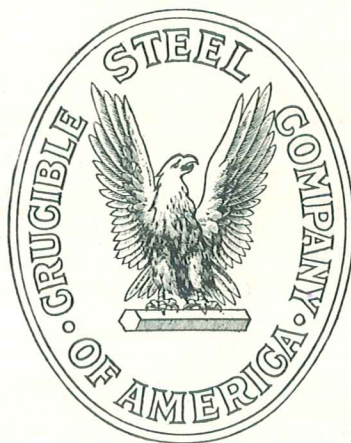


# CRUCIBLE STEEL COMPANY OF AMERICA

Makers of Fine Steels

The Industry that Serves All Industry

High Speed and Tool Steels  
Rezistal Stainless Steels  
Alloy and Machinery Steels  
Special Steels for Special Needs  
In All Commercial Forms



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Executive and Sales Offices  
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# CRUCIBLE STEEL COMPANY OF AMERICA

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## INTRODUCTION

The development of corrosion and heat resisting steels began nearly twenty years ago, but little attention was given to them until after the end of the World War. This was partly due to the fact that the use of chromium, which is an important constituent in all of these products, was not permitted other than for wartime uses during that period. Since that time the evolution of such products has gone forward rapidly and constitutes the outstanding development in the use of alloy steels since the introduction of high speed steels in the year 1900.

The CRUCIBLE STEEL COMPANY OF AMERICA has been engaged in the manufacture of the hardenable chromium type, which is principally used in the manufacture of cutlery, for nearly eighteen years. During the war period we developed in our own laboratories a group of stainless and heat resisting products generally designated as the non-hardenable austenitic chromium-nickel steels. In our earliest products silicon was present to the extent of 2 per cent and over for the purpose of enhancing the heat resisting properties of our steels. Following several years of research work we publicly introduced these materials in 1920 and, so far as we are aware, this is the first public demonstration of wrought austenitic chromium-nickel steels in America. The materials were displayed in the form of bars, sheets and wire.

Since this first presentation of these products improvement has been made in them and additional products have been added to the original group until today the REZISTAL steels are considered the standard in many industries using corrosion and heat resisting steels.

The industrial and economical importance of these products has been remarkably demonstrated during the past five depression years, for while the general production of steel declined very seriously between 1929 and 1933, the production of stainless steels was practically the same in those two years, leading us to believe that, with the return of prosperity, their growth will be very much faster and that many new industrial applications for such products will appear.

The use of REZISTAL steels and of other brands has become so widespread in recent years that it seems imperative to offer something more explicit in regard to them than can be found in the usual catalog. In the following pages, therefore, features of the different corrosion and heat resist-

ing steels will be presented in such a way as to permit the prospective user to judge which type of steel may be best suited to his particular application.

These steels may be classified in three groups, namely:

- Group I. Non-Hardenable Austenitic Chromium-Nickel Steels.
- Group II. Hardenable Chromium Steels.
- Group III. Non-Hardenable Chromium Steels.

The following chart will indicate the essential properties of the products falling within these three groups. The individual characteristics of the various materials in each group will be described in detail later, indicating also their particular fields of application. The best choice of the proper material is not always a question merely of resistance to corrosion; the strength and other mechanical characteristics desired and the limitation of the available means of fabrication are frequently the deciding factors in selection between several materials all of which may present satisfactory resistance to corrosion.

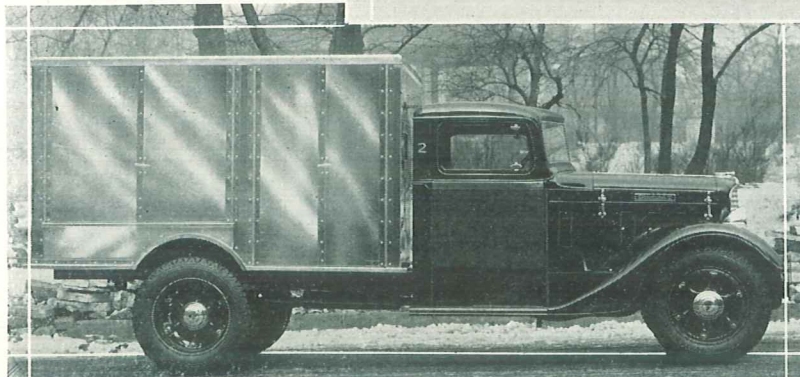
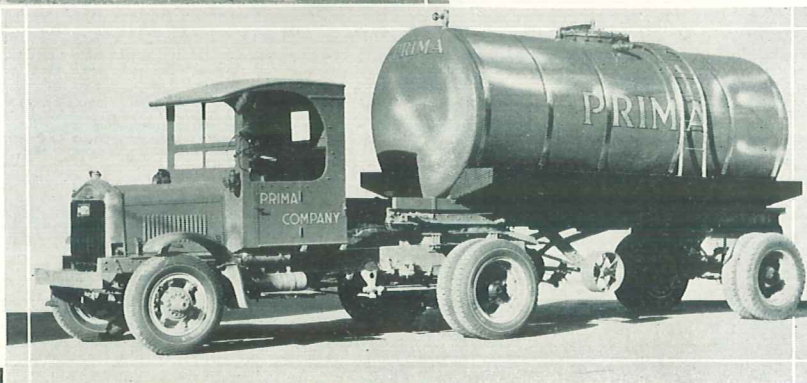
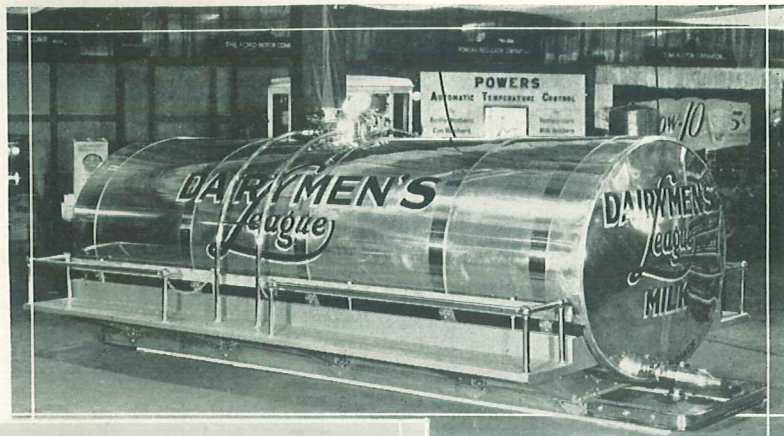
This chart and the information in the succeeding pages will give some indication of the materials available for any given set of conditions, but the data should not be construed as a definite recommendation since many variables, incapable of tabulation, influence the best choice.

For new and untried applications it is always advisable to conduct a test on the proposed material under actual operating conditions. In some cases where a large investment is contemplated it has been found desirable to construct a small or pilot plant. Often this may be impossible and a laboratory test, simulating as nearly as possible actual conditions, must be substituted.

Accumulated experience in connection with installations employing the corrosion and heat resisting steels is, in many cases, sufficient to warrant definite recommendation in certain applications, but one cannot be sure that conditions which seem to be identical are identical. Therefore, the safest thing to do is to conduct the tests under actual operating conditions, as far as possible. The table is presented merely to indicate the group which may be most suitable for any particular application. It is suggested that inquiry be submitted to us so that we may give you the benefit of our experience and our research covering nearly a score of years in this field of activity.



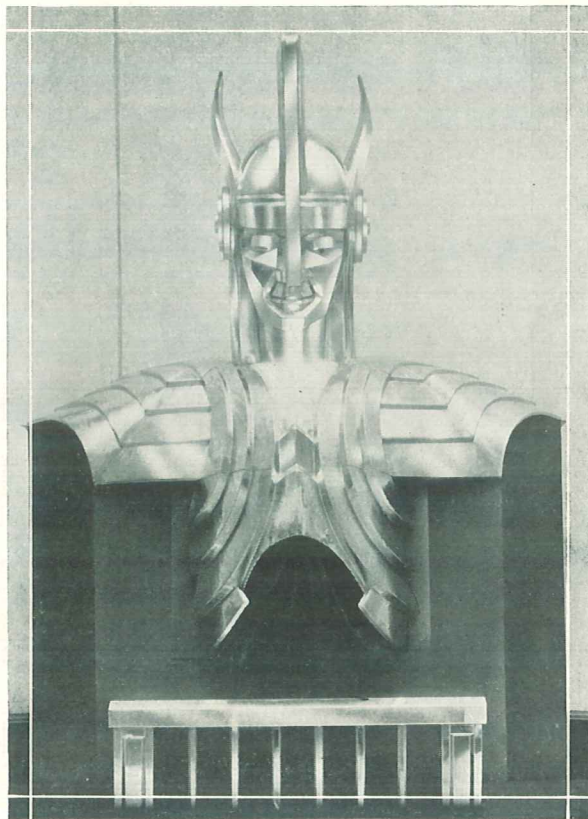
# CRUCIBLE STEEL COMPANY OF AMERICA



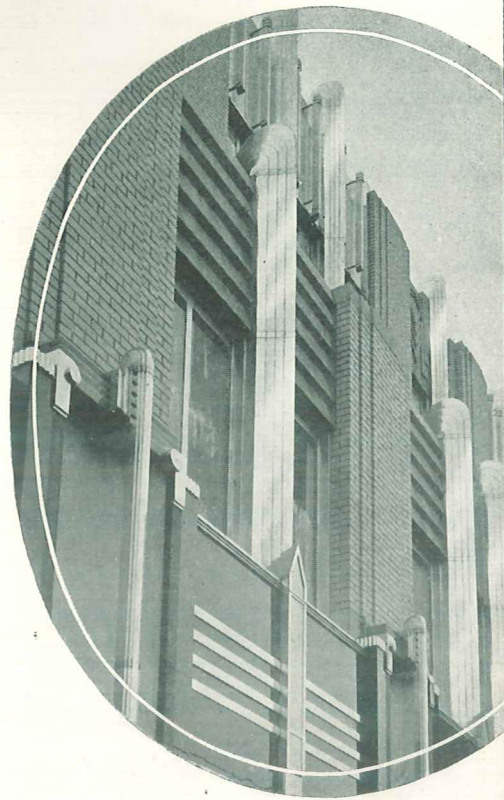
TRUCK TANKS of REZISTAL for Milk, Beer and Bakery Products



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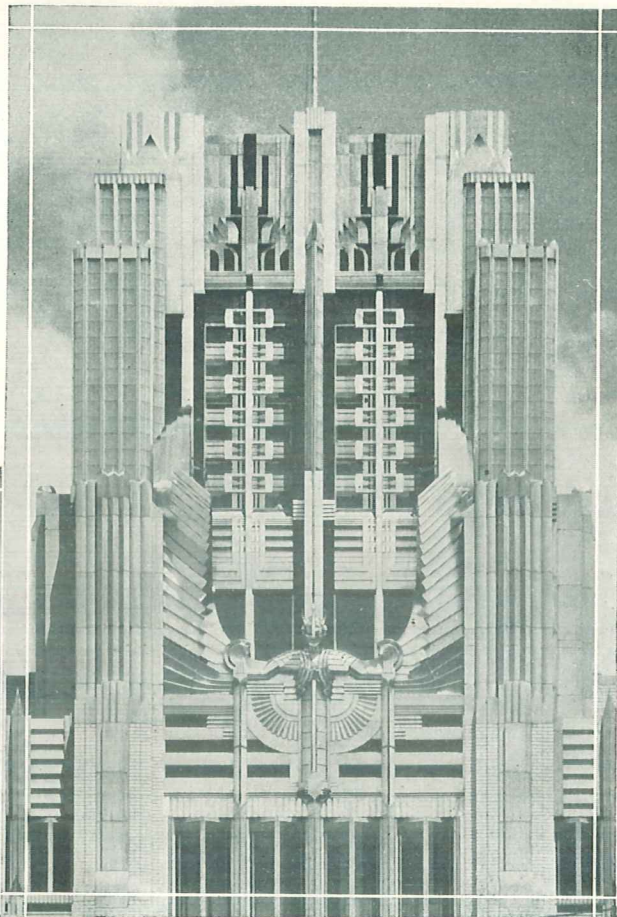


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Interesting Applications of





REZISTAL for Architectural Trim

# CRUCIBLE STEEL COMPANY OF AMERICA

## GROUP I

Non-Hardenable Austenitic Chromium Nickel Steels

	REZISTAL KA2	REZISTAL 2C	REZISTAL 4	REZISTAL 7
	KA2S	KA2SMO	7 (NCT3)	
	KA2ST	3	2600	
	FM188	3C		
CORROSION RESISTANCE	Best resistance of any group. Resistant to salt water and a wide variety of acids, alkalies and chemical compounds. REZISTAL KA2 or its modifications satisfactory for most applications, although very severe corroding media may require the use of REZISTAL KA2SMO, REZISTAL 3, REZISTAL 4 or REZISTAL 7.			Satisfactory water, n
*SCALE RESISTANCE	REZISTAL 2C ..... 1700° F.	REZISTAL 4 ..... 2000° F.	REZISTAL 3 ..... 1950° F.	REZISTAL 7 ..... 2100° F.
	REZISTAL 3C ..... 2050° F.			
STRENGTH	Excellent strength—not variable by heat treatment, but can be greatly increased by cold work.			Can be engineer
STRENGTH AT HIGH TEMPERATURE	Best Available			Good up
TOUGHNESS	Excellent			Good
HOT WORKING	Satisfactory			Satisfac
COLD WORKING	Satisfactory work hardens with severe cold work.			Satisfac
DEEP DRAWING	Excellent			Fair
SPINNING	Good (see REZISTAL KA2SFS)			Fair
FORMING	Excellent			Good
MACHINING	The Free Machining types are recommended where extensive machining is to be done.			Satisfac machini
WELDING	Easiest welding group. Most generally recommended for welded construction. When a similar welding rod is used there is no hardening of the parent metal or weld deposit. A good ductile weld results. See notes on inter-granular corrosion.			Satisfac
RIVETING	Satisfactory			Satisfac
TEMPERATURES TO BE AVOIDED IN HEAT TREATMENT OR SERVICE	REZISTAL KA2, 2C, 4, 2600, 3, 3C, 7 ..... 1000° to 1500° F.			900-110
	REZISTAL KA2S, KA2ST, KA2SMO ..... slight, if any			
PRICE	Most expensive			Least e

\*NOTE: Scale resistance is not merely a function of temperature encountered is quite important. The temperatures given, are an indication of what might be expected. Different atmospheric conditions upward or downward.



el Steels

REZISTAL 4

" 7 (NCT3)

" 2600

GROUP II

Hardenable Chromium Steels

REZISTAL STAINLESS IRON 12

" " " FM2

" " " STEEL GRADE A

" " " " B

" " " " B100

" " " " BM

GROUP III

Non-Hardenable Chromium Steels

REZISTAL STAINLESS IRON 17

" " " 20

" " " 27

ry of acids, alkalies and chemical applications, although very severe 3, REZISTAL 4 or REZISTAL 7.

Satisfactory resistance to corrosion of the atmosphere, fresh water, mild acids, fruit juices, and vegetable juices.

Generally better resistance than Group II, but generally not as good as Group 1, for severe conditions. SATISFACTORY for Nitric Acid in most concentrations. Corrosion resistance generally increases with increasing chromium contents.

..... 2000° F.  
..... 2100° F.

Up to 1200° F.

REZISTAL STAINLESS IRON 17.....1650° F.  
" " " 20.....1800° F.  
" " " 27.....2100° F.

increased by cold work.

Can be heat treated to as wide a range of strengths as most engineering alloy steels.

Good strength, but not responsive to heat treatment.

Good up to 1200° F.

Fair

Good

Fair

Satisfactory

Satisfactory

Satisfactory

Satisfactory

Fair

Good

Fair

Fair

Good

Good

g is to be done.

Satisfactory. The Free Machining types possess excellent machining properties.

Satisfactory

struction. When a similar welding A good ductile weld results. See

Satisfactory. Should be annealed after welding.

Satisfactory. Anneal after welding improves ductility and corrosion resistance. If subjected to severe impact in service, riveting is preferred.

Satisfactory

Satisfactory

.....1000° to 1500° F.  
.....slight, if any

900-1100° F.

800-1000° F.

Least expensive

Intermediate in price

nce is not merely a function of temperature. The atmosphere important. The temperatures given, are, therefore, merely an ht be expected. Different atmospheres may cause a variation

## GENERAL PROPERTIES OF THE REZISTALS

The various REZISTALS cover the field of corrosion and heat resisting steels more completely than any other group commercially available. There is a REZISTAL for every imaginable application for which corrosion and heat resisting steels can be used, and in a wide variety of mechanical properties.

There are certain corroding media for which there are, at present, no steels satisfactorily resistant. Such media would include the higher concentrations of the Halogen Acids such as Hydrochloric Acid, Hydrofluoric Acid, Hydrofluosilic Acid, etc., and Sulphuric Acid at high temperatures and in certain concentrations.

### Resistance to Corrosion

The Non-Hardenable Austenitic Chromium Nickel Steels of Group I are the most generally resistant to corrosion. They are resistant to salt water, a wide variety of acids, alkalies and chemical compounds, as indicated by the tables on pages 5 to 13.

The Hardenable Chromium Steels of Group II are not as resistant to Nitric Acid as those of Group III but, in general, can be used for resistance to

atmospheric and fresh water, mild acid and alkali, and fruit juice corrosion.

The Non-Hardenable Chromium Steels of Group III are intermediate between Groups I and II, in resistance to corrosion. They are satisfactory for Nitric Acid, both hot and cold, in most concentrations and are suitable for resistance to atmospheric, fresh water and sea water corrosion as well as to corrosion by the milder acids, alkalies and fruit juices.

### Loss Conversion Table

Different investigators and different specifications express corrosion losses in different units. The units most frequently used are included in the table below and the conversion factors for

translating one form of expression into another, we believe, will prove very useful, particularly to readers of technical literature.

Grams per sq. centimeter per hour	Milligrams per sq. decimeter per day	Grams per sq. meter per hour	Grams per sq. inch per hour	Grams per sq. foot per day	Grams per sq. foot per month	Inches penetration per month 7.8 sp. gr.	Inches penetration per year 7.8 sp. gr.
1	2,400,000	10,000	6.45	22.300	669,000	36.8	441
.0000004	1	.00116	.000003	.00935	.279	.00015	.000184
.0001	240	1	.000645	2.25	66.9	.00368	.0441
.155	372,000	1,550	1	3,460	104,000	5.71	68.5
.000049	180	.448	.000289	1	30	.00165	.0198
.0000015	3.59	.0149	.000009	.0333	1	.000055	.00056
.0271	65,000	271	.175	605	18,200	1	12
.00226	5,420	22.6	.0146	50.5	1,515	.0833	1

### How to Use the Table

A few examples will make clear the method of using these conversion figures.

1. **To Convert:** .000082 grams per square centimeter per hour to inches penetration per year. . . . From the chart we see 1 gram per square centimeter per hour = 441 inches of penetration per year. Thus .000082 grams per square centimeter per hour = .000082  $\times$  441 = .036162 inches penetration per year.

2. **To Convert:** .00048 grams per square inch per hour to inches penetration per year. . . . From

the chart we see 1 gram per square inch per hour = 68.5 inches of penetration per year. Thus .00048 grams per square inch per hour = .00048  $\times$  68.5 = .03288 inches of penetration per year.

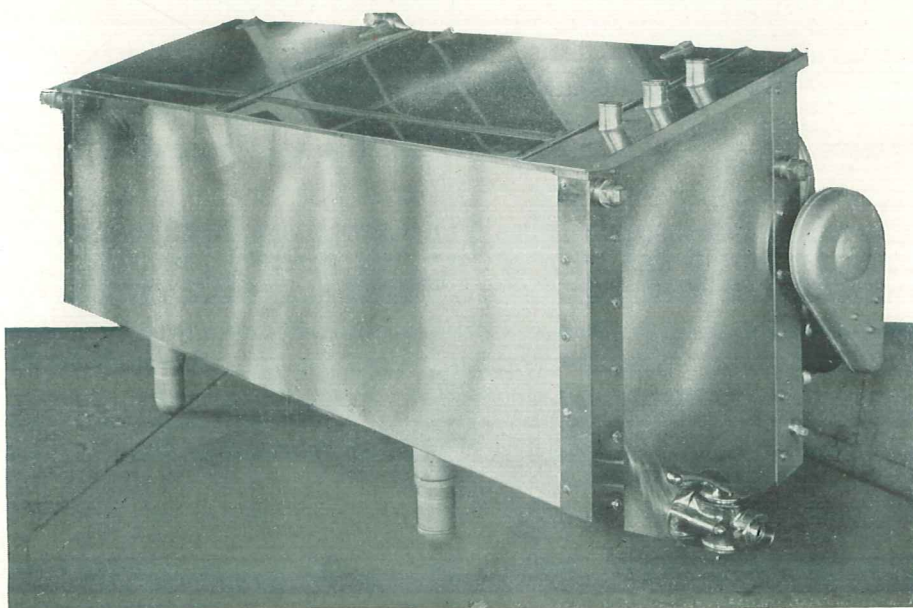
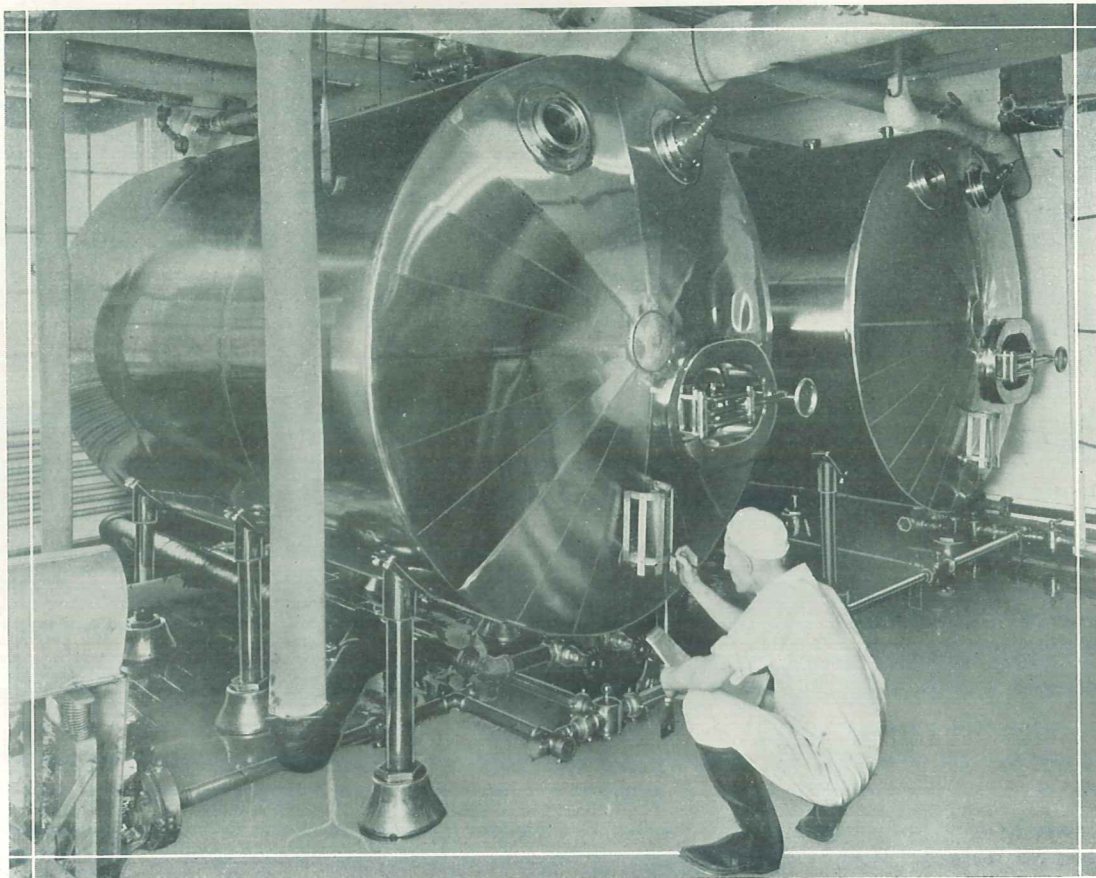
3. **To Convert:** .022 inches per year to grams per square centimeter per hour. . . . From the chart we see 1 inch per year = .00226 grams per square centimeter per hour. Thus .022 inches per year = .022  $\times$  .00226 = .00004972 grams per square centimeter per hour.



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CRUCIBLE STEEL COMPANY OF AMERICA

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Milk and Cream Pasteurizer and Boiler of REZISTAL

# CORROSION AND HEAT RESISTING STEELS

## RESISTANCE TO VARIOUS CORROSIVE AGENTS

The data presented in the following pages will prove of very great interest and use if the reader will recall that corrosion losses are not "physical constants," but that the exact loss reported at any one time depends upon a great many variables, including the nature of the corroding medium, its concentration, temperature, and degree of aeration, while under the same conditions a sample of corrosion resistant material would give rather widely different results depending upon the physical condition in which the steel exists at the time of the test.

For this reason the data presented regarding two of the most important Austenitic Chromium-Nickel Steels are divided into five classes. In the lists the numerals indicate the following degrees of resistance:

- I.—Fully Resistant
- II.—Satisfactorily Resistant
- III.—Fairly Resistant
- IV.—Slightly Resistant
- V.—Non-Resistant

These designations are somewhat arbitrary, obviously, but are based on practical experience with the various materials and the various corroding media. For example, the grade designated as "fully resistant," means that in the tests a loss of weight, in grams per square meter per hour, is less

than 0.1, or expressed in the more familiar units used in the United States, this represents a loss of less than 0.0044 in. of penetration per year, based upon an assumed specific gravity of 7.8 and 365 days per year at a uniform rate of corrosion. In many cases the rate of corrosion is not uniform. It may be quite rapid initially and cease altogether; or it may begin at a moderate rate and increase.

For this reason the data given may not be taken as a guarantee of definite and specific losses which may be expected with REZISTAL KA2 or REZISTAL KA2SMO, and because of the many variables entering into the problem of corrosion testing it is always recommended that samples of the material, whose use is contemplated, be tried out under actual operating conditions. The impurities under commercial conditions may exert an effect that would not be present when dealing with chemically pure materials in a laboratory test.

Also the condition of the material, as furnished by the mill, may be somewhat changed during the course of fabrication, due to the setting up of stress conditions and also due to welding operations and the variable thermal disturbances due to the welding process. After fabrication, and before putting into service, it is highly desirable to pickle or to give a passivating treatment in 20 per cent nitric acid at 150°F.



MEDIA	CONCENTRATION	Tested at °C	Rezistal KA-2	Rezistal KA-2 SMO
Acetic Acid	10% Spec. Gravity 1.01	20	I	I
		Boiling	I	I
	50% Spec. Gravity 1.06	20	I	I
		Boiling	I	I
	80% Spec. Gravity 1.07	20	I	I
		Boiling	III	I
	100% Spec. Gravity 1.05	20	I	I
		Boiling	II	I
Acetic Anhydride	100% but at 150 lb. pressure	200	V	II
		Boiling	I	I
Acetone		Boiling	I	I
		Cold	II	II
Acetylene Chloride		Boiling	II	II
		20	I	I
Acid Mine Water				



# CRUCIBLE STEEL COMPANY OF AMERICA

MEDIA	CONCENTRATION	Tested at °C	Rezistal KA-2	Rezistal KA-2 SMO
Acid Salt Mixtures	Nitric Acid fuming, Spec. Gravity 1.52 plus 10% Potassium Nitrate	Boiling	II	II
	Nitric Acid, fuming, Spec. Gravity 1.52 plus 10% Aluminum Nitrate	Boiling	II	II
	Sulphuric Acid, 10% Spec. Gravity 1.07 plus 10% Copper Sulphate	Boiling	I	I
	Sulphuric Acid, 10% Spec. Gravity 1.07 plus 2% Ferrous Sulphate	Boiling	I	I
Activine	Aqueous Solution	20	I	I
Alcohol		20 & Hot	I	I
Alkaline Liquor	20% Spec. Gravity 1.23	Boiling	I	I
(Sodium Hydroxide Solution)	34% Spec. Gravity 1.37	100	I	I
		Boiling	II	II
Aluminum	Molten	750°	V	
Aluminum Acetate	Aqueous Solution Cold Saturated	20	I	I
	"	Boiling	I	I
Aluminum Potassium	Aqueous Solution 10%	20	I	I
Sulphate	"	Boiling	II	I
(Alum)	" Saturated Hot	Boiling	III	II
Aluminum Sulphate	Aqueous Solution 10% Neutral	20	I	I
	"	Boiling	II	I
	Saturated Aqueous Sol. Neutral	20	I	I
	"	Boiling	III	II
Ammonia	Aqueous Solution			
	Spec. Gravity 0.91	20	I	I
(Gas Liquor)	"	Boiling	I	I
	" Saturated with Sodium			
	Chloride—Cold	20	I	I
	" Saturated at 100°C with			
	Sodium Chloride	100	I	I
Ammoniacal Water	Boiling		I	
Ammonium Bicarbonate	Aqueous Solution	20	I	I
	"	Hot	I	I
Ammonium Chloride	Aqueous Solution 10%	Boiling	I	I
(Sal Ammoniac)	" 20%	Boiling	I	I
	" 50%	Boiling	II	II
Ammonium Nitrate	Solution Saturated at 100°	Boiling	I	I
	Dissolved in con. H <sub>2</sub> SO <sub>4</sub>	60	I	I
	"	120	I	I
Ammonium Sesqui-carbonate	Aqueous Solution, Cold Satur.	Boiling	I	I
Ammonium Perchlorate	Aqueous Solution 10%	Boiling	I	I
Ammonium Sulphate	Aqueous Solution 10%	Boiling	I	I
	" Saturated Cold	Boiling	I	I
Ammonium Sulphite	Aqueous Solution, Con.	20	I	I
	"	Boiling	I	I
Ammonium Stannichloride	Aqueous Solution, Cold Satur.	20	II	
(Pink Salt)	"	60	V	
Antimony	Molten	600	V	
Baking Soda	(See Sodium Bicarbonate)			
Barium Chloride	Aqueous Solution	Hot	II	II
Barium Nitrate	Aqueous Solution		I	I
Beer	Barley Malt and Hops:	20	I	
	Alcohol 3.5—4.5%			
	"	70	I	

# CORROSION AND HEAT RESISTING STEELS

MEDIA	CONCENTRATION	Tested at °C	Rezistal KA-2	Rezistal KA-2 SMO
Beet Juice (Sugar Beet Juice)			I	I
Benzene		20	I	I
		Boiling	I	I
Benzine (Coal Tar Product)		Hot	I	I
Benzine (Crude Oil)		Hot	I	I
Benzol		Hot	I	I
Bichloride of Mercury	Dilute Solution 0.1%	20	I	I
	"	Boiling	I	I
	" 0.7%	20	II	II
	"	Boiling	IV	IV
Bleaching Powder	See Chloride of Lime			
Bleaching Solution containing Chlorine		20	II	I
Boric Acid—Conc.		Boiling	I	I
Blue Vitriol	See Copper Sulphate			
Bromine		20	V	V
Butyric Acid	Spec. Gravity 0.96	20	I	I
	"	Boiling	I	I
Calcium Bisulphite	Aqueous Solution, Spec. Gravity 1.04	Boiling	I	I
	" at 300 lbs. pressure	200	V	I
Calcium Brine		20	I	I
Calcium Brine	Adulterated with Sodium Chloride	20	I	I
Calcium Chlorate	Dilute Solution	20	I	I
	"	Hot	I	I
Calcium Chloride	See Chloride of Lime			
Calcium Hypochloride (Chloride of Lime Bleaching Powder)	Aqueous Solution 5°BE	40	III	II
	Spec. Grav. 1.04			
Cane Juice (Sugar Cane)		Hot	I	I
Carbolic Acid	C. P.	Boiling	I	I
	Raw	Boiling	I	I
	Raw	100	I	I
Carbonate Soda (Soda Ash)	Aqueous Solution 5%	Boiling	I	I
	" 50%	Boiling	I	I
	Melting	900	V	V
Carbon Tetrachloride	(Anhydrous)	Room Tem	I	
Carbon Tetrachloride	"	Boiling	I	
Carbonic Acid in Water	(Charged Water)		I	I
Carnallite	Cold Saturated Solution	Boiling	II	II
Caustic Potash	(See Potassium Hydroxide)			
Cellulose			I	I
Charged Water	(See Carbonic Acid in Water)			
Chili Saltpeter	(See Sodium Nitrate)			
Chinosol	Used as an antiseptic			
	Aqueous Solution 1:500	20	I	I
Chlorate of Lime	Aqueous Solution	Hot	I	I
Chloride of Lime	Aqueous Solution Saturated Cold	100	I	I
Chloride of Sulphur		20	I	I
Chlorine	Gas, Dry	20	I	I
	Gas, Moist	20	IV	III
	Gas, Moist	100	V	V
	Saturated Cold	20	II	II
Chlorinated Water		Boiling	I	I
Chlorobenzene			I	I
Chloroform			I	I
Chromic Acid	Aqueous Solution, not C. P. contains SO <sub>3</sub> , 50%, Spec. Gravity 1.51	20	I	I
	"	Boiling	V	V



# CRUCIBLE STEEL COMPANY OF AMERICA

MEDIA	CONCENTRATION	Tested at °C	Rezistal KA-2	Rezistal KA-2 SMO
Chromic Acid (cont.)	C. P. Aqueous Solution 10%, Spec.			
	Gravity 1.07, free of SO <sub>3</sub> .	20	II	II
	"	Boiling	II	II
	C. P. Aqueous Solution 50%, Spec.			
	Gravity 1.51, free of SO <sub>3</sub>	20	I	I
	"	Boiling	III	III
	Chromelectrolyte (Grube)	20	I	I
Chrome Alum	Aqueous Sol. Spec. Gravity 1.6	Boiling	V	
	Ditto, plus Ferrous Sulphate	100	II	
Citric Acid	Aqueous Solution, 10%	20	I	I
	"	Boiling	I	I
	" 25%	20	I	I
	"	Boiling	IV	I
	" 50%	20	I	I
	"	Boiling	IV	I
	" 5% at 45 lbs. pressure	140	II	I
Copperas	See Ferrous Sulphate			
Copper Acetate	Moistened with water	20	I	
Copper Chloride	Aqueous Solution 10%	Boiling	V	V
Copper Cyanide	Solution Saturated at 100°C	Boiling	I	
Copper Nitrate	See Cupric Nitrate			
Copper Sulphate (Blue Vitriol)	Solution Saturated at 100°C	Boiling	I	I
Cream of Tartar	(See Potassium Bitartrate)			
Cresote (Coal Tar)		Hot	I	I
Cresote Oil		Hot	I	I
Cupric Nitrate	50% Aqueous Solution	Hot	I	I
Cyanogen			I	I
Dichloro-ethane		Boiling	I	
Ethyl Alcohol	10% Spec. Gravity at 20°—0.98	20°	I	I
(Spirit of Wine)	50% Spec. Gravity at 20°—0.91	20°	I	I
	95% Spec. Gravity at 20°—0.80	20°	I	I
	100% Spec. Gravity at 20°—0.79	20°	I	I
Distillery Wort			I	I
Dyewood Liquor			I	I
Dutch Liquor	See Ethylene Chloride			
Epsom Salt Solution	See Magnesium Sulphate			
Ferric Hydroxide				
(Hydrate Iron Oxide)		20	I	I
Ferric Chloride (Iron Chloride)	Dilute Solution	20	V	V
Ferrous Sulphate	Aqueous Solution 10%	20	I	I
	"	Boiling	I	I
Formaldehyde	Aqueous Solution 40%	20	I	I
(Methanal) (Formalin)	"	Boiling	I	I
Formalin	See Formaldehyde			
Fruit Juices		Hot	I	I
Fuel Oil		Hot	I	I
Gallic Acid	Saturated at 100°C	Boiling	I	I
Gasolene			I	I
Glauber's Salt	See Sodium Sulphate			
Glue		Hot	I	I
Glycerine			I	I
Grape Juice (Waste Acids)		20	I	I
Gypsum	See Sulphate of Lime			
Hops			I	I
Hydrated Iron Oxide	See Ferric Hydroxide			
Hydrochloric Acid	Diluted 1:85—Sp. Gr. 1.002	20	II	II
(Muriatic Acid)	"	Boiling	V	V

# CORROSION AND HEAT RESISTING STEELS

MEDIA	CONCENTRATION	Tested at °C	Rezistal KA-2	Rezistal KA-2 SMO
Hydrochloric Acid (cont.) (Muriatic Acid)	Diluted 1:10—3.6% Sp. Gr. 1.017	20	III	II
	“	Boiling	V	V
	Vapors—	20	II	II
	“	100	IV	IV
	“	500	IV	IV
	“	20	I	I
Hydrocyanic Acid (Prussic Acid)		20	I	I
Hydrofluoric Acid Vapors		100	II	II
Hydrofluosilic Acid		20	V	V
	Vapors	100	II	II
Hydrogen Peroxide (See Peroxide Hydrogen)				
Hydrogen Sulphide (See Sulfuretted Hydrogen)				
Hyposulphite of Soda (Sodium Thiosulfate, Hypo)	Dilute	Hot	I	I
Iodine	Dry	20	I	I
	Moist	20	V	V
		50	I	
Iodoform				
Iron Gall Ink	Contains: Ferrous Sulphate, Iron Tannates, Iron Gallates and some Acid	20	I	I
	“	Boiling	I	I
Iron Chloride	See Ferrous Chloride			
Kerosene			I	I
Lactic Acid	Spec. Gravity 0.96	20	I	I
	“	Boiling	I	I
Lard		20 Hot	I	I
Lead	Molten	600	II	
Lead Acetate	Aqueous Solution	Boiling	I	I
Linseed Oil		20 Hot	I	I
Linseed Oil and Sulphuric Acid	3%	200	I	
Lye (Caustic)	See Sodium Hydroxide See Potassium Hydroxide			
Lysol			I	I
Manganese Chloride	Aqueous Solution, 10% and 50%	Boiling	I	I
Magnesium Chloride	Solution	Hot	III	III
Magnesium Oxychloride			III	III
Magnesium Sulphate (Epsom Salt Solution)		Hot	I	I
		20	I	I
Marsh Gas			I	I
Mash		Hot	I	I
Mercuric Bichloride	0.7%	20	II	II
Mercuric Chloride (Sublimate)	Aqueous Solution 0.1%	20	I	I
	“	Boiling	I	I
	“ 0.7%	20	II	II
	“	Boiling	IV	IV
Mercury	Liquid	20	I	I
		50	I	I
Methanal	See Formaldehyde			
Methylene Chloride		Boiling	I	
Methyl Aldehyde	Aqueous Solution 40%	20	I	I
		Boiling	I	I
Milk, Sweet and Sour			I	I
Molasses			I	I
Mixed Acids (per cent in weight)	50% Conc. Sulphuric Acid plus 50% conc. nitric acid	50—60	I	I
	“	90—95	II	II
	“	Boiling (120°)	III	III



# CRUCIBLE STEEL COMPANY OF AMERICA

MEDIA	CONCENTRATION	Tested at °C	Rezistal KA-2	Rezistal KA-2 SMO
Mixed Acids (cont.) (per cent in weight)	75% Conc. Sulphuric Acid plus 25% conc. Nitric Acid	50—60	I	I
	“	90—95	II	II
	“	Boiling (157°)	IV	IV
	70% Conc. Sulphuric Acid plus 10% Conc. Nitric Acid plus 20% Water	50—60	I	I
	“	90—95	II	II
	“	Boiling (168°)	V	V
	30% Conc. Sulphuric Acid plus 5% Conc. Nitric Acid plus 65% Water	50—60	I	I
	“	90—95	I	I
	“	Boiling (110°)	II	II
	15% Conc. Sulphuric Acid plus 5% conc. Nitric Acid plus 80% Water	50—60	I	I
	“	90—95	I	I
	“	Boiling (104°)	I	I
Mixtures of Acids and Salts	Fuming Nitric Acid, Sp. Gr. 1.52 <i>Plus 10% Potassium Nitrate</i>	Boiling	II	II
	Fuming Nitric Acid, Sp. Gr. 1.52 <i>Plus 10% Aluminium Nitrate</i>	Boiling	II	II
	Sulphuric Acid, 10% Sp. Gr. 1.07 <i>Plus 10% Copper Sulphate</i>	Boiling	I	I
	Sulphuric Acid, 10% Sp. Gr. 1.07 <i>Plus 2% ferrous Sulphate</i>	Boiling	I	I
Muriatic Acid	See Hydrochloric Acid			
Naphtha			I	I
Naphtha Crude			I	I
Naphthalene Sulphonic Acid		20	I	I
Nickel Chloride	Solutions	20	I	I
Nickel Sulphate	Solutions	20 Hot	I	I
Nitre	See Potassium Nitrate			
Nitric Acid	Diluted 1:10 Spec. Gravity 1.04	20	I	I
	“	Boiling	I	I
	1:1 Spec. Gravity 1.23	20	I	I
	“	Boiling	I	I
	Concentrated, Sp. Gr. 1.40	20	I	I
	“	Boiling	II	II
	Concentrated, fuming, Sp. Gr. 1.52	20	I	I
	“	Boiling	IV	IV
	Oleic Acid	150	I	I
	“	200	I	I
Oil, Crude (Asphalt Base)		Hot	I	I
Oil, Crude (Paraffine Base)		20	I	I
Oil, Lubricating (Light or Heavy)			I	I
Oil, Mineral			I	I
Oil, Vegetable			I	I
Oxalic Acid	Aqueous Solution 10%	20	I	I
	“	Boiling	IV	II
	“ 25%	Boiling	IV	II
	“ 50%	Boiling	III	II
Paraffine		Hot	I	I

# CORROSION AND HEAT RESISTING STEELS

MEDIA	CONCENTRATION	Tested at °C	Rezistal KA-2	Rezistal KA-2 SMO
Perhydrol	(See Peroxide of Hydrogen)			
Phenol	(See Carbolic Acid)			
Peroxide of Hydrogen	(No influence through catalysis)	20	I	I
Petroleum			I	I
Petroleum Ether			I	I
Phosphoric Anhydride	Dry	20	I	I
	Moist	20	I	I
Phosphoric Acid	1% Spec. Gravity 1.00	20	I	I
	"	Boiling	I	I
	" at 45 lbs. Pres.	140	I	I
	10% Spec. Gravity 1.05	Boiling	I	I
	45% Spec. Gravity 1.30	Boiling	I	I
	80% Spec. gravity 1.64	60	I	I
	"	110	V	III
Phosphoric Acid, C. P.	Any Strength	80—90	I	I
Photographic Developers	All have reducing properties: Hydroquinone, Amidol, Ferrous- Potassium Oxalate	20	I	
	"	Boiling	I	
Pink Salt	See Potassium Nitrate			
Plaster of Paris	See Sulphate of Lime			
Potash	See Potassium Carbonate			
Potassium Alum	See Alum			
Potassium Bitartarate	Saturated	Boiling	II	II
Potassium Bichromate	Aqueous Solution 25%	Boiling	I	I
Potassium Carbonate (Potash)	Solution	Hot	I	I
Potassium Chlorate	Saturated	Boiling	I	I
Potassium Chloride	Solution	Boiling	I	I
Potassium Chrome Alum	See Chrome Alum			
Potassium Dichromate	Aqueous Solution 25%	Boiling	I	I
Potassium Hypochlorite	Concentrated Solution	20	II	II
Potassium Ferricyanide	Aqueous Solution 25%	20	I	I
(Red Prussiate of Potash)	"	Boiling	I	I
Potassium Hydroxide	27% Solution, Spec. Gravity 1.25	Boiling	I	I
(Caustic Potash)	50% Solution, Spec. Gravity 1.54	Boiling	II	II
	Melting	360	V	V
Potassium Nitrate	50% Solution	20	I	I
(Nitre) (Saltpeter)	"	Boiling	I	I
	Melting	550	I	I
Potassium Permanganate	Aqueous Solution	Boiling	I	I
Potassium Sulfuret	See Potassium Sulphide			
Potassium Sulphate	Solution	Hot	I	I
Potassium Sulphide	Solution	Hot	I	I
(Potassium Sulfuret)				
Prussic Acid	See Hydrocyanic Acid			
Quinosol	Aqueous Solution 1:500	20	I	I
Red Prussiate of Potash	See Potassium Ferricyanide			
Salammonia	See Ammonium Chloride			
Salt	See Sodium Chloride			
Salt Brine	3% Solution	20	I	I
	Over 3% Solution	20	I	I
Saltpeter	See Potassium Nitrate			
Sea Water	100g contain: NaCl—2.72g; MgCl <sub>2</sub> —0.33g; MgSO <sub>4</sub> —0.22g; CaSO <sub>4</sub> —0.13g; KCl—0.97g; MgBr <sub>2</sub> —0.008g; CaCO <sub>3</sub> —0.012g	20	I	I



# CRUCIBLE STEEL COMPANY OF AMERICA

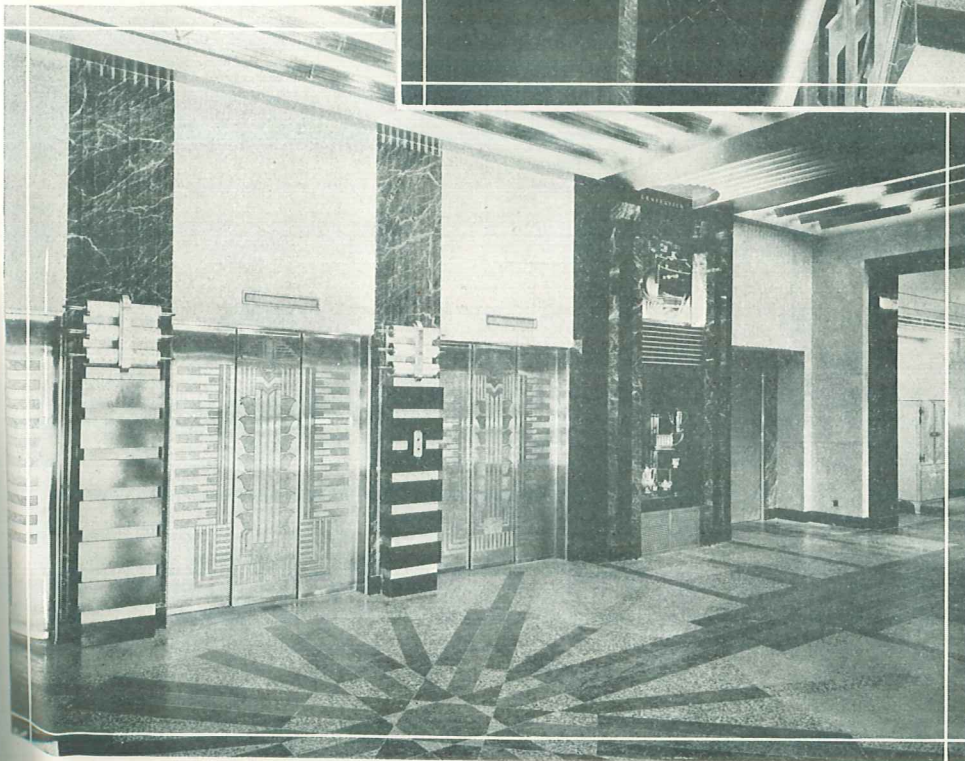
MEDIA	CONCENTRATION	Tested at °C	Rezistal KA-2	Rezistal KA-2 SMO
Sewage			I	I
Silver Nitrate	Aqueous Solution 10%	Boiling	I	I
Slop Liquor			I	I
Soda	Aqueous Solution 10%	Boiling	I	I
(Sodium Carbonate)	Cold Saturated Solution	Boiling	I	I
Soda Ash	See Carbonate of Soda			
Soda Nitre	See Sodium Nitrate			
Sodium Bicarbonate	Solution	20	I	I
(Baking Soda)				
Sodium Bisulphate	Aqueous Solution 10%	20	I	I
	"	Boiling	I	I
Sodium Bisulphite	Aqueous Solution, Spec. Gr. 1.38	20	I	I
Sodium Carbonate	See Carbonate of Soda			
Sodium Chloride	Cold Saturated Solution	20	I	I
	Solution Saturated at 100°	Hot	II	II
Sodium Hydroxide	20% Solution	110	I	
	34% Solution	100	I	
	Melting	318	II	II
Sodium Hypochlorite	Aqueous Solution, Spec. Gr. 1.21	20	II	II
Sodium Perchlorate	Aqueous Solution 10%	20	I	I
	"	Boiling	I	I
Sodium Hyposulphite	See Hyposulphite of Soda			
Sodium Nitrate	Solution	Hot	I	I
(Chili Saltpeter Soda Niter)				
Sodium Peroxide	Aqueous Solution 10%	20	I	I
	"	95	I	I
Sodium Sulphate	Solution	Hot	I	I
(Glauber's Salt)				
Sodium Sulphide	Aqueous Solution 50%	Boiling	I	I
Sodium Sulphite	Aqueous Solution 50%	Boiling	I	I
Sodium Thiosulphate	Aqueous Solution 25%	20	I	I
	"	Boiling	I	I
Spirit of Wine	See Ethyl Alcohol			
Stannic Chloride	See Tetrachloride of Tin			
Stannous Chloride		50	II	
Starch	Solution		I	I
Strontium Hydroxide			I	I
Strontium Nitrate	Solution	Hot	I	I
Sublimate	See Mercuric Chloride			
Sublamin	Aqueous Solution 1:500	20	I	I
Sugar	Solution	Hot	I	I
Sugar Beet Juice	See Beet Juice			
Sugar Cane	See Cane Juice			
Sulfuretted Hydrogen				
(Hydrogen Sulphide)		20	I	I
Sulphate of Lime,				
(Plaster of Paris Gypsum)			I	I
Sulphide of Hydrogen		20	I	I
Sulphide of Sodium	50% Solution	Boiling	I	I
	Cold Saturated Solution	Boiling	I	I
Sulphur	Fused	130	I	
	Boiling	445	III	III
Sulphur Monochloride		20	I	I
Sulphur Dioxide	Gas (Moist)	20	II	I
	"	300	I	I
Sulphurous Acid in Water	Cold Saturated Solution	20	I	I
	at 60 lbs. pressure	135	I	I

# CORROSION AND HEAT RESISTING STEELS

MEDIA	CONCENTRATION	Tested at °C	Rezistal KA-2	Rezistal KA-2 SMO
Sulphurous Acid in Water (Cont.)				
(Sulphur Dioxide—Sulphu- rous Anhydride SO <sub>2</sub> )	at 70—125 lbs. pressure	160	III	II
	at 150 lbs. pressure	180	III	II
	at 200 lbs. pressure	200	III	II
	at 300 lbs. pressure	200	III	II
Sulphuric Acid	Diluted 1:20 Spec. Gravity 1.03	20	I	I
	“	Boiling	V	IV
	Diluted 1:10 Spec. Gravity 1.10	20	I	I
	“	Boiling	V	V
	Diluted 1:1 Spec. Gravity 1.52	20	I	I
	“	Boiling	V	V
	Con. 1:0 Spec. Gravity 1.84	20	I	I
	“	100	IV	IV
	“	100	IV	IV
	“	150	V	V
	Fuming (11% Free SO <sub>3</sub> ) Sp. Gr. 1.91	100	II	II
	“ (60% free SO <sub>3</sub> ) Spec. Gr. 2.00	20	I	I
	“	70	I	I
Sweet Water		Hot	I	I
Syrup		Hot	I	I
Tannic Acid	Aqueous Solution, 10%	20	I	I
	“ 50%	Boiling	I	I
	“	20	I	I
	“	Boiling	I	I
Tanning Liquor			I	I
Tar			I	I
Tar and Ammonia in Water			I	I
Tartaric Acid	Aqueous Solution, 10%	20	I	I
	“	Boiling	I	I
	“ 50%	20	I	I
	“	Boiling	I	I
Tetachloride of Tin	Solution	20	IV	III
(Stannic Chloride)	Spec. Gravity 1.21	Boiling	V	V
Tin	Molten	600	V	
Trichloroethylene		Boiling	I	
Turpentine Oil		35	I	I
Uric Acid		20	I	I
Vinegar	(See also Acetic Acid)	Hot	I	I
Vitriol Blue	See Copper Sulphate			
Vitriol Green	See Ferrous Sulphate			
Vitriol White	See Zinc Sulphate			
Water Hot			I	I
Water Oily			I	I
Water Salt		20	I	I
Whiskey			I	I
Wood Pulp			I	I
Wort			I	I
Yatrene	Aqueous Sol. Saturated	20	I	I
Yeast			I	I
Zinc	Molten	600°	V	
Zinc Chloride	Aqueous Solution, Sp. Gr. 2.05	40	I	I
	“ Sp. Gr. 1.09	Boiling	IV	I
Zinc Chloride	78°BE	35	I	
Zinc Cyanide	Moistened with water	20°	I	I
Zinc Nitrate	Solution	Hot	I	I
Zinc Sulphate	25% Solution	Cold	I	I
(White Vitriol)	25% Solution	Boiling	I	I
	Saturated			



CRUCIBLE STEEL COMPANY OF AMERICA



REZISTAL Interior Architectural Trim



### **Intergranular Corrosion**

All 18 per cent Chrome-8 per cent Nickel Steels such as REZISTAL KA2 are Austenitic in character, which means that all the important constituents of the alloy are in solid solution within the grains and the steel is non-magnetic. Unless the carbon is very low, these steels will precipitate carbides (presumably chromium carbide) at the grain boundaries when heated within the range of 1000°F. to 1500°F. When these steels are then exposed to active electrolytes, the zone of precipitated carbides is subject to failure by a phenomenon known as intergranular corrosion. This failure is accompanied by extreme brittleness in the zone of precipitated carbides. There may be no surface indication of corrosion whatever, but sudden failure may occur due to intergranular attack.

Welding naturally produces a temperature gradient in the article being welded ranging from a melting temperature at the weld to room temperature at some distance removed from the weld. Therefore, some portion between these two extremes will have been subjected to the temperature range of 1000°F. to 1500°F.

An annealing treatment at 1800°F., or above, depending on conditions, will cause the precipitated carbides to be re-absorbed by the grains making the material homogeneous once more, and not sub-

ject to intergranular attack. However, it is not always possible or desirable to anneal after fabrication, in which case the use of REZISTAL KA2S, REZISTAL KA2ST, REZISTAL KA2SMO, or some other alloy resistant to intergranular corrosion, is recommended.

For welded applications, incapable of annealing after welding, subject to powerful electrolytes, it is necessary to use REZISTAL KA2ST or REZISTAL KA2SMO. For applications involving only moderate electrolytes it is satisfactory to use REZISTAL KA2S. In other words, reducing the carbon to .07 maximum reduces the amount of carbide that can be precipitated, which is sufficient precaution for use with weak electrolytes; but where strong electrolytes are encountered, this is not enough and titanium or some other element that will produce delta iron or stable carbides is necessary. For applications involving constant high temperature operations, within the dangerous temperature range, the use of REZISTAL KA2SMO rather than REZISTAL KA2 is preferable. For detailed information as to the method of welding, see instructions under WELDING, pages 25-27 and pages on REZISTAL KA2S, REZISTAL KA2ST, and REZISTAL KA2SMO.

### **Strength**

The Non-Hardenable Austenitic Chromium Nickel Steels of GROUP I possess in general a tensile strength of from 80,000 to 100,000 lbs. per square inch in the annealed condition with excellent ductility. This strength cannot be increased by heat treatment, but can be materially increased by the cold working of thin sections. It is possible to secure as high as 200,000 lbs. tensile strength per square inch in cold rolled strip, and as high as 250,000 lbs. per square inch tensile strength in cold drawn wire. These steels do not suffer any great loss in impact strength or ductility at temperatures as low as that of liquid air.

The Hardenable Chromium Steels of Group II can be hardened and tempered to yield a wide

range of strengths and ductility, ranging from 70,000 to 200,000 lbs. per square inch tensile strength.

The Non-Hardenable Chromium Steels of Group III possess, in general, a tensile strength of from 75,000 to 85,000 lbs. per square inch which cannot be materially varied by heat treatment; and can be only moderately increased by cold work.

The Non-Hardenable Austenitic Chromium Nickel Steels of Group I harden on cold working and, therefore, rubbing contact can produce a work hardened skin surface which is quite resistant to abrasion.

### **Resistance to Abrasion**

The Non-Hardenable Austenitic Chromium Nickel Steels of Group I being susceptible to work-hardening, develop splendid resistance to abrasion on rubbing surfaces.

The Hardenable Chromium Steels of Group II can be heat treated to secure good resistance to abrasion due to their high hardness. Some users

have reported that the steels in this group are twice as resistant to abrasion as plain carbon or low alloy steels of equal hardness.

The Non-Hardenable Chromium Steels of Group III possess no particular abrasion resisting properties.



CRUCIBLE STEEL COMPANY OF AMERICA



REZISTAL Kitchen Equipment





# CORROSION AND HEAT RESISTING STEELS

## Surface Appearance

All of the REZISTALS are capable of taking a ground and polished surface in a wide variety of finishes and lustres ranging from a dull gray or silvery pickled finish, through the popular ground satin finish up to the highly polished mirror finish.

An important characteristic of these steels is that they maintain their polish for indefinite periods of time, subject, of course, to the amount of dust and soot that might settle upon their surface. Dirt is easily removed by merely washing with soap and warm water. The lustre immediately returns.

Sheets of the various REZISTALS can be obtained in several surface finishes as indicated by the following numbers:

Finish No. 1.	Hot rolled, Annealed and Pickled
Finish No. 2B.	Full Finished (bright cold rolled)
Finish No. 2D.	Full Finished (dull cold rolled)
Finish No. 4.	Standard Commercial Polish
Finish No. 6.	Commercial Polish (Tampico brushed)
Finish No. 7.	High Lustre Polish
Finish No. 8.	Mirror Polish

NOTE: The most generally used polished finish is No. 4 (ground one or both sides)

## Resistance to Scaling and Heat

Some of the corrosion resistant steels are very resistant to scaling at elevated temperatures. There are others in the family of heat and corrosion resisting steels that are used exclusively for high temperature service. There are still others having particular virtue because of their strength at elevated temperatures and resistance to creep.

Generally speaking, steels other than those in the heat and corrosion family can be used for strength and non-scaling properties at temperatures below 1200°F. See pages on LO CRO 46 and its modifications.

For temperatures over 1200°F., the following steels can be used up to the temperatures indicated. It must be borne in mind, however, that resistance to scaling is not merely a function of the temperature, but is influenced greatly by the atmosphere prevailing at any particular temperature. Therefore, the upper limits listed as follows do not apply to all atmospheres, and may be lower or higher depending upon the atmosphere.

Rezistal Stainless Iron 17.....	1650° F.
Rezistal 2C .....	1700° F.
Rezistal Stainless Iron 20.....	1800° F.
Rezistal 3 .....	1950° F.
Rezistal 4 .....	2000° F.
Rezistal 3C .....	2050° F.
Rezistal 7 .....	2100° F.
Rezistal Stainless Iron 27.....	2100° F.

Fabricating characteristics enter to a large degree into the choice of the proper material for any application. Hence where the parts are to

be welded or where the best strength at elevated temperatures is desired, the choice lies among the steels of Group I, namely REZISTAL 2C, REZISTAL 3, REZISTAL 3C, REZISTAL 4, or REZISTAL 7. Where operating conditions include frequent excursions into the 1000°F. to 1500°F. embrittling temperature range, the use of the Group III steels is suggested, provided welding is not used.

For strength at elevated temperatures, REZISTAL KA2SMO has been found to possess the greatest strength and creep resistance in high heat service. It should be borne in mind that the steels of Group III, namely REZISTAL STAINLESS IRON 17, 20, and 27, are not as ductile in the cold as the steels in Group I, namely REZISTAL 2C, 3, 3C, 4, and 7. And the steels of Group III, when cooled slowly through an 800°F. to 1000°F. range, or when long maintained at that range, become quite brittle at room temperature. This room-temperature brittleness is not present at elevated temperature. The Chromium Steels of Group III are generally recommended for exposures to high sulphur atmospheres if fabrication or low-temperature brittleness does not present a problem.

The choice between REZISTAL 4 and REZISTAL 7 for elevated temperature use depends to a large extent upon the atmosphere encountered. REZISTAL 4 should be used when the percentage of SO<sub>3</sub> gas is high, whereas REZISTAL 7 is used if the percentage of SO<sub>2</sub> gas is high.

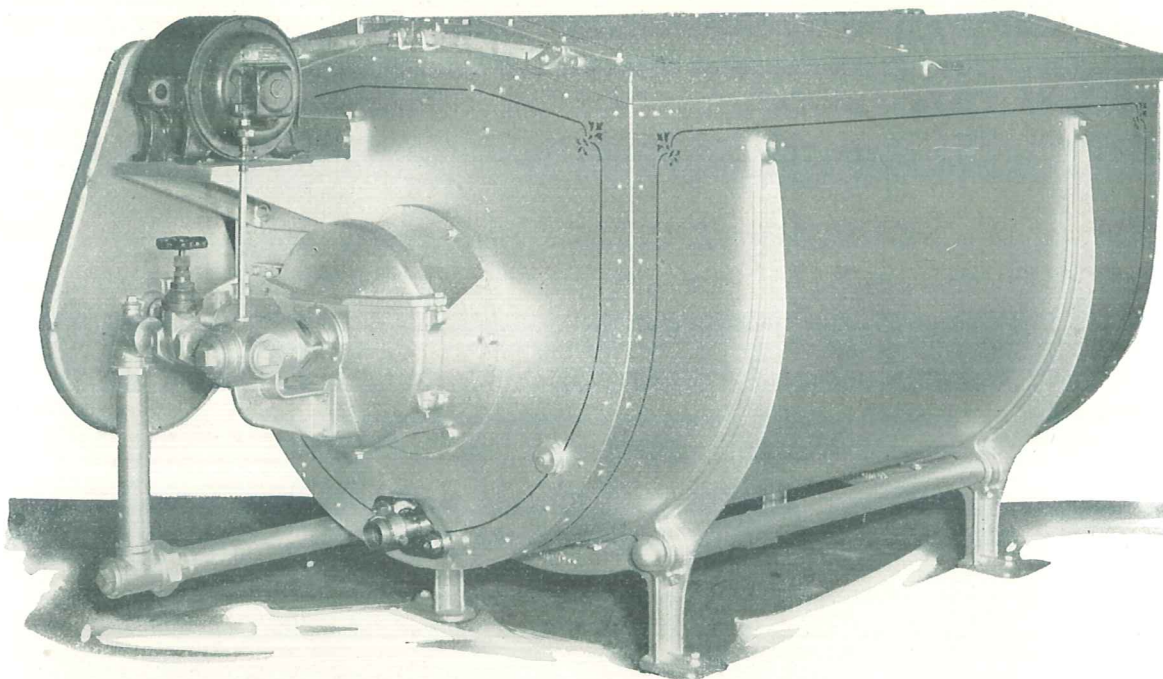
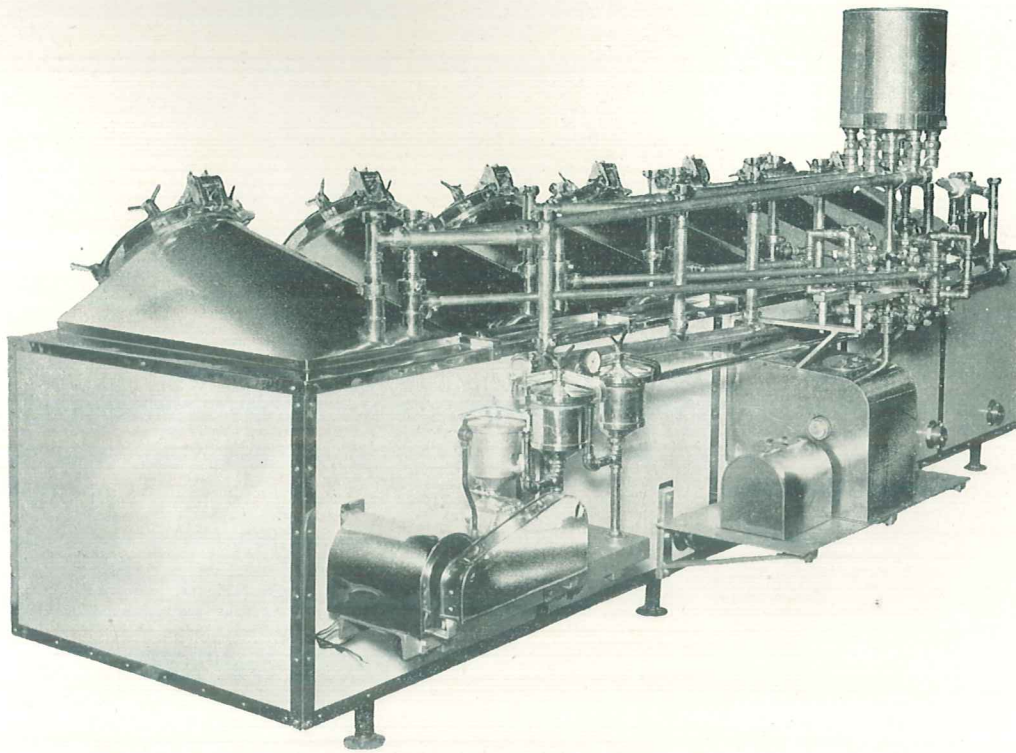




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CRUCIBLE STEEL COMPANY OF AMERICA

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REZISTAL in the Dairy Industry

## **GENERAL WORKING AND FABRICATING PROPERTIES**

### **Forging**

The corrosion resisting steels have a lower thermal conductivity than ordinary carbon or low-alloy steels. Therefore longer time at heat is necessary to assure uniform heating throughout the mass. With the higher Carbon types of Group II such as REZISTAL STAINLESS STEELS, Grade A, B, B100 and BM, as well as large billets, blooms or ingots of all the grades, a preheat at 1500°F. to 1600°F. is recommended, followed by a rather rapid heating up to the proper forging

temperature. When a preheat is used, the time at the forging temperature should be sufficient to allow thorough heat penetration, but soaking at the high temperature should be avoided. The proper forging temperature for each grade is given under the description of that grade. In all cases the first blows of the hammer should be light ones. Steels of Group II have marked air-hardening properties, and should be slowly cooled after forging.

### **Annealing**

The details of annealing practice are given under the description of each grade.

### **Hardening**

Steels in Groups I and III cannot be hardened by heat treatment, although steels in Group I, in small or thin sections, can be hardened by cold

work such as cold drawing or cold rolling.

Steels in Group II can be hardened in oil or air from 1750°F. to 1900°F.

### **Tempering**

After hardening, the steels in Group II can be tempered to a wide variety of mechanical proper-

ties, as indicated under the individual types of that group.

### **Pickling**

The forging and hardening of steels in Group II often forms a tenacious scale which is frequently loosened by sand blasting before pickling. For scale removal only on all three groups one of the following solutions is generally used, the second and third being more vigorous:

1. 10% Sulphuric Acid at 150° F.
2. 10% Sulphuric Acid plus 10% Rock Salt at 150° F.
3. A 50% solution of Hydrochloric Acid at 160° F. is sometimes used for severely scaled articles.

This is always followed by a rinse in warm water and then by a dip in 20 per cent Nitric Acid at 150°F., followed by another rinse in warm water.

For a bright silvery finish the following solution is used, followed by a hot water rinse.

1. 10% Nitric Acid plus 3% Hydrochloric Acid at 160° F.

**NOTE:** Never leave any of these steels in the pickling solution longer than necessary to remove scale, as the result of overpickling is both dangerous and wasteful. It is better to pickle for a short time and then scrub with a wire brush to further loosen the scale, then repickle, rather than to try to remove all of a tenacious scale in one pickle.

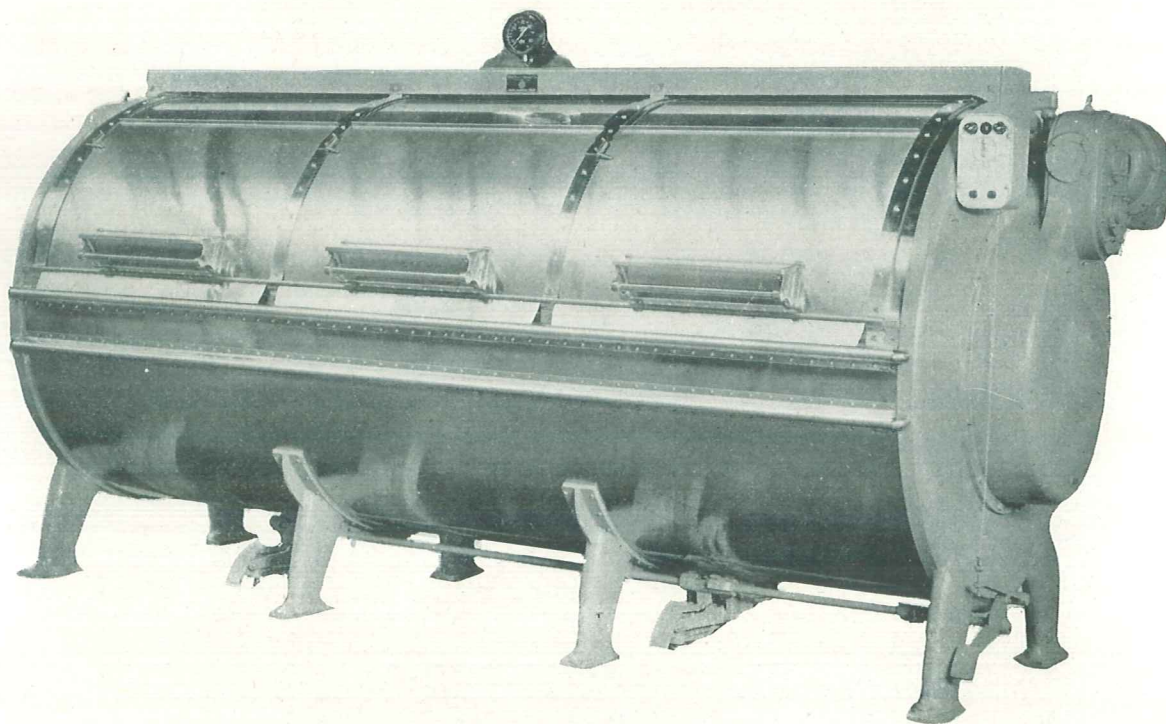
Irrespective of what pickling solution is used, the last operation should be a thorough washing in warm water.



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REZISTAL in Laundry Equipment



## Passivating

All corrosion resisting steels are such because their alloy content allows the building up of a tough, passive oxide film on the surface. The building up of this surface can be hastened by an immersion in cold 20 per cent Nitric Acid for 30 minutes, or preferably in 20 per cent Nitric Acid at about 150°F. This is called passivating. This Nitric Acid dip should be followed immediately by a thorough washing in cold water, otherwise

staining will result. Passivating does not affect the appearance of a polished surface, and should always be used after polishing, grinding, shearing, cutting, and machining, as it removes any particles of the cutting or grinding tool that might be embedded in the material or any of the polishing compounds or other foreign matter that might adhere to the surface. It is general practice to passivate after fabrication or after severe handling.

## Forming and Drawing

The Austenitic Chromium Nickel Steels of Group I are by far the easiest to form and draw. Of the steels of Group I, the REZISTAL KA2 family is the most readily formed and drawn. On the other hand Austenitic Steels of Group I work harden when severely cold worked. It, therefore, is necessary in severe deep drawing work to resort to intermediate anneals when the material has work hardened to an extent that further drawing is impractical.

When in the annealed condition REZISTAL STAINLESS IRON 12 and REZISTAL STAINLESS IRON FREE-MACHINING 2 of Group II can be formed successfully and drawn, although these operations will require more power than is required on the steels of Group I. The other grades of Group I can be formed when in the annealed condition, but not as readily as REZISTAL KA2, and require more intermediate annealing.

The steels of Group III may be successfully formed and deep drawn, although slightly more power is required for drawing these steels than is required for Group I. The forming operations on this group present no difficulties.

The use of solid steel dies is recommended. Our HYCC DIE STEEL has proven ideal in many applications, particularly where large runs are desired. For limited runs cast iron dies are somewhat cheaper and have been used with success. For the steels of Groups II and III only slightly greater die clearances than are used for ordinary deep drawn stock are satisfactory. However, for the Austenitic Chromium Nickel Steels of Group I, about twice the die clearance allowed on regular deep drawn stock should be used. This clearance varies with the shape, size and gauge of material to be drawn.

With REZISTAL KA2 a maximum reduction of about 50 per cent can be obtained before re-annealing. In other words a 10-inch diameter blank can be drawn in one operation into a 5-inch cup before reannealing is necessary.

An allowance for spring back of two to three times that for ordinary steels should be made.

It has been found advisable in all cases, when

deep drawing these steels, to use a drawing lubricant. The water-soluble lubricants are preferred. A mixture of castor oil and emulsified soap has been found quite satisfactory. Other lubricants with a lithopone base are in wide use. One consists of a mixture of lithopone, pale paraffin oil No. 2 cup grease, flour of sulphur, and talc. For heavy work, a mixture of one half linseed oil and one half white lead has been used with success.

The lithopone base lubricants can be removed easily by washing with gasoline, kerosene or by a caustic dip followed by scrubbing. Always thoroughly remove the lubricant before annealing, otherwise the decomposition of the lubricant at the annealing temperature will cause trouble.

When drawing a polished surface it is often the practice to protect the surface with paper pasted on with ordinary flour-and-water paste. It is recommended that a fairly heavy paper, but not a glazed or waterproof paper, be used for the double purpose of assuring a better bond and for easy removal by dissolving in water.

Care must be taken to prevent any die scratches. Polished dies should be used. Scratches must be removed by fine grinding before buffing.

Where intermediate anneals are required a temperature of 1900°F. to 1950°F. is recommended, followed by an air cool. The article should not be held at this high temperature any longer than is necessary to insure thorough penetration of the heat. For the final anneal see annealing instructions under each grade.

It is usual practice to re-strike after the final pickle. Split dies may produce scratches of such magnitude that coarse grinding will be needed to eliminate them. So they are not recommended.

Following the anneal, the material should be pickled by one of the methods described. The bright pickle solution of 10% Nitric Acid plus 3% Hydrochloric Acid at 150°F. is recommended.

For intricate forming and drawing operations requiring an exceptionally easy drawing material the use of REZISTAL KA2SFS is suggested. See details on this grade under REZISTAL KA2.

An hydraulic press has been found to be better for drawing REZISTAL than a toggle press.



# CRUCIBLE STEEL COMPANY OF AMERICA



REZISTAL in Cafeterias





## Spinning

See page 41 on REZISTAL KA2SFS. (Free Spinning.)

REZISTAL KA2 and KA2S have been spun more readily than the other corrosion resisting steels. Even they have presented some difficulty due to the work hardening tendencies of Austenitic Steels. THE CRUCIBLE STEEL COMPANY OF AMERICA has developed a special grade for spinning operations that has met with great success, and regardless of what previous experience has been it is urgently suggested that anyone desirous of spinning a corrosion resistant steel try REZISTAL KA2SFS. It should prove a revelation.

Even free spinning stock will require an intermediate anneal after the material has been suffi-

ciently work hardened to make further spinning impractical. This anneal should consist of heating the article to 2000°F. for sufficient time to insure penetration of the heat followed by air cooling. An oil or gas fired muffle or semi-muffled furnace with a fairly neutral atmosphere should be used. For the gauges that are usually spun, three to six minutes in a furnace at temperature should be sufficient.

A soap lubricant should be used in spinning and this lubricant should be washed off before annealing. After annealing, the article should be pickled before further spinning is attempted.

A fairly blunt spinning tool is recommended for this work.

## Grinding and Polishing

The amount of grinding and polishing required depends largely upon the mill finish of the sheets used and on the finish desired for a particular application, purpose or specification. In general, a hot rolled pickled sheet requires Nos. 80, 120, 150, 180, and 200 mesh abrasive for grinding, whereas sheets and strips, which have received some cold rolling such as our full finish or number two finish, require Nos. 120, 150, 180, and 200 or less. It is essential that all marks and scratches from previous grinding be removed before starting with a finer grinding. The best method is to use a soft grease wheel covered with an abrasive of about the hardness of silicon carbide. For greasing the wheel, a grease of high melting point should be used, preferably of stearic base. Petrolatum base greases have too low a melting point and do not hold the grinding compound. When an abrasive is used, care should be taken to assure that it is iron free.

Due to the fact that the REZISTALS of Group I are non-magnetic, a magnetic chuck cannot be used for this group. The speed of the wheel is an important factor. Speeds for grinding should not exceed 8000 feet per minute, and 6000 to 8000 feet is best. This on a 14-inch wheel requires spindle speeds of 1750 to 1800 rpm.

For buffing, a speed of about 8500 to 12,000 feet per minute should be used, which, for a 14-inch buffing wheel, means a spindle speed of about 2400 rpm.

The grinding and polishing operation, assuming that hot rolled pickled sheet is used, can be

sub-divided as follows:

### A. Materials formed in one operation without an intermittent anneal

1. Give sheet or blank grinding in lard oil at Nos. 80, 120, 150, 180 and 200 grit.
2. Form articles (Protect the surface)
3. Tampico brush or buff depending on desired finish.

### B. Materials formed in more than one operation with an intervening anneal

1. Give sheet or blank machine grinding in lard oil at Nos. 80, 120, 150, 180 and 200 grit.
2. First drawing operation.
3. Anneal and pickle.
4. Finish drawing.
5. 200 grit greasing.
6. Tampico brush or buff depending on finish desired.

Experience has shown that annealing and pickling, if properly carried out, will not destroy a ground finish imparted to the stock. For buffing, wide wheels with green chrome oxide grease stick should be used. After materials are finished, the polish can be preserved and any cleaning done by using cheesecloth dusted with powdered slaked lime or commercial whiting. Never use a red rouge polish or any other polish containing iron.

If satin or brush finish is desired, stop with Tampico brushing. All grinding and polishing should be done with the least possible pressure. Never clean REZISTAL KA2 with a steel wire brush. Always use a brush of the same material or a non-metallic brush.

## Riveting

All three grades may be successfully riveted, although the splendid welding characteristics of Group I have made riveting less common in their particular case. Group I should be riveted at 1950° F. Group II should be riveted at 1600° F. to 1700° F. Group III should be riveted at not over 1400° F.—this is important,

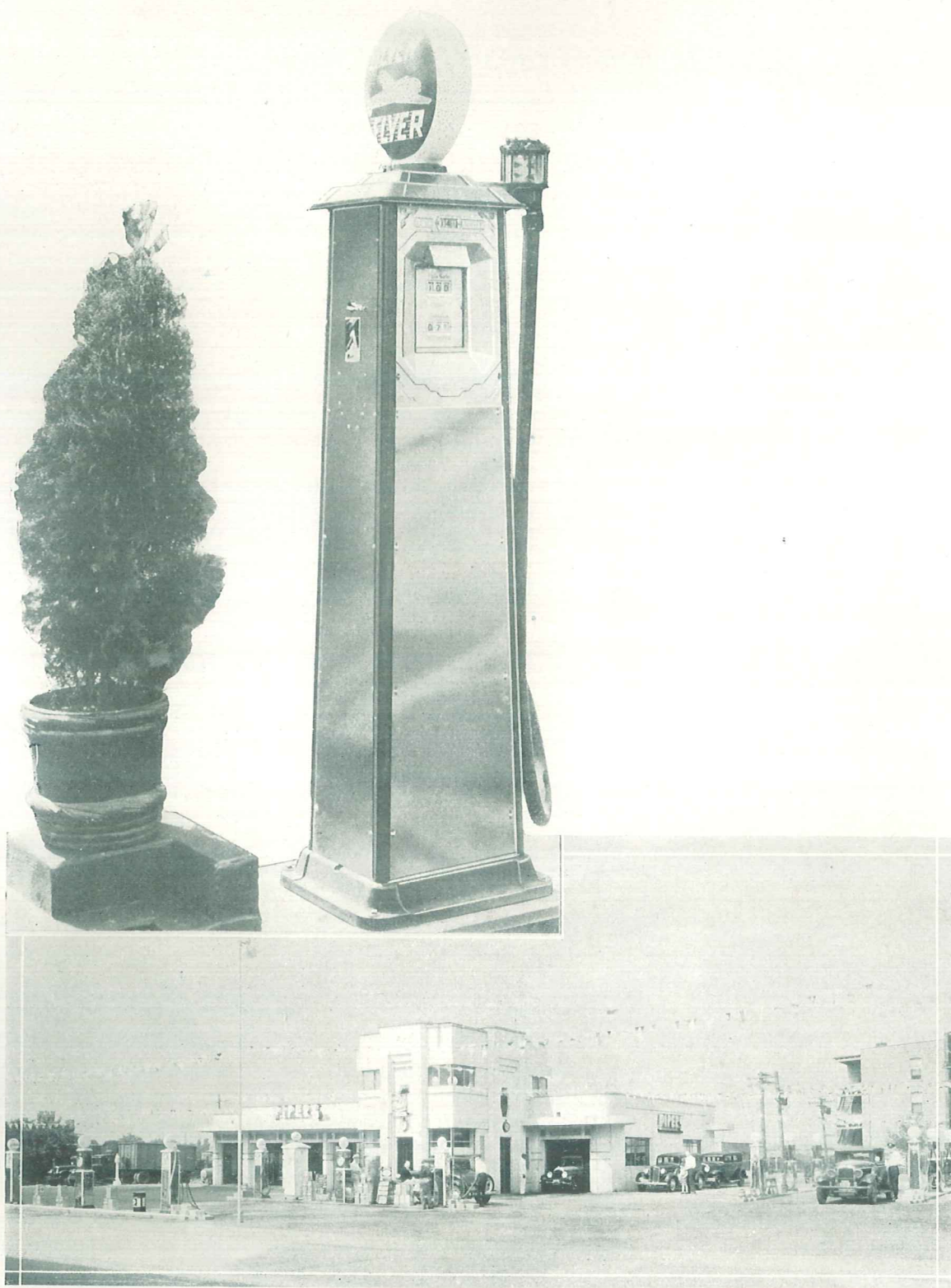
as otherwise the rivet will be low in impact value and have reduced resistance to corrosion. In all three groups the rivets should have a clean pickled surface before heating, and the heating should be done in an indirectly fired furnace—never in an open fire. Rivets of small sizes may be driven cold.



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CRUCIBLE STEEL COMPANY OF AMERICA

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REZISTAL for Gasoline Service Station Decoration and for Gasoline Pumps



## Welding

Important—See comments on Intergranular Corrosion on page 15

Welding has been found to be the ideal method of joining the various Austenitic grades of Group I. It can be used to join the steels of Group II but must be followed by an annealing treatment. Grade III steels may be welded unless subjected to severe impact shock in service. An anneal after welding improves ductility and corrosion resistance.

The methods generally used are the electric arc method and the gas method. The choice of method depends upon two factors; i.e., the thickness of the material to be welded and the equipment available. Sheets heavier than 16 gauge are generally welded by the electric arc method. Gas welding lends itself better to lighter gauges, although there are several high frequency electric arc welding machines on the market, which are most adaptable to welding light gauge material. Recently spot welding (or shot welding, as it is sometimes called) has been used with great success on the corrosion resisting steels. Spot welding is particularly successful on hard rolled REZISTAL KA2 of high tensile properties, as the time at heat is not sufficient to reduce the high tensile properties induced by cold working. Likewise the time at heat is not sufficient to cause susceptibility to intergranular corrosion.

The diameter of the welding rod should be approximately the same as the thickness of the sheet to be welded, otherwise an unequal length of time will be necessary for the heat to penetrate the rod and the sheet. The following table will prove useful in choosing the proper size rod to use for various sheet thicknesses:

Up to 16 gauge—	3/32" dia. rod
16 to 8 gauge—	1/8" dia. rod
8 gauge to 3/16"—	5/32" dia. rod
3/16" and heavier	3/16" dia. rod

In all cases a REZISTAL welding rod of the same grade as the parent metal should be used, with the exception of REZISTAL KA2ST parent metal, when a REZISTAL KA2S rod should be used unless constant operation at elevated temperatures is anticipated, in which case a REZISTAL KA2SMO rod is to be recommended.

Often it is desirable to grind the welded area of the finished job so that the weld will not be perceptible to the eye. In these instances, the weld should be ground down to nearly the polished surface with a rubberset wheel. Then grit fabric wheels should be used starting with No. 60 grit; then using No. 80 grit and then No. 120 grit. Tallow or grease can be added to the 120 grit wheel so as to get the same degree of polish on the welded area as on the balance of the sheet.

## Gas Welding

When gas welding is used the following practice has been found to give good results:

1. The sheets should be clamped tightly to a smooth flat surface (preferably copper) so that when the heat from the torch flame is applied the sheets will not twist and buckle.

2. Use a tip in the torch just large enough to melt and cause the metal to flow. This allows the operator to go across the joint carefully and slowly enough to eliminate the possibility of porosity.

Porosity is due usually to the operator's using so much heat that he must rush the welding operation in order to avoid burning holes in the sheet.

3. A neutral to slightly reducing flame should be used; i.e., a very slight excess of acetylene. This excess should be kept at a minimum at all times and watched very closely, due to its tendency to add carbon to the deposited metal.

4. The flame of the torch should be directed in the direction of the joint to be welded. This

enables the operator to use the excess heat of the flame to preheat the material ahead of the spot being welded, thus conserving time.

5. While it is possible to cut narrow strips from the sheet itself and use these as filler rod we have found that the operator can make much better time and do a better looking job with a perfectly smooth cold drawn rod of the required diameter.

6. Thorough penetration of the deposited metal is sometimes quite difficult to obtain with this method of welding, therefore it is suggested that on butt welding, the sheets be spaced slightly apart.—the spacing depending upon the thickness of sheet and the amount of penetration desired.

7. The technique employed is to see that the both sheets are melting before adding any filler rod, then keep the metal in a molten condition the length of the weld and, if possible, keep the end of the filler rod in the molten puddle and melt it from this position.



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CRUCIBLE STEEL COMPANY OF AMERICA

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REZISTAL Pasteurizer



REZISTAL Dye Kettles

## Electric Arc Welding

If the following practice is pursued, successful welds should be obtained. These rules however are merely the fundamentals and some practice will be required by the operator to develop a suitable technique for production welding:

1. The polarity of the welding machine should be in the reversed position; the work to be negative and the electrode or welding wire to be positive. In welding mild steel the opposite is the practice.

2. The metal to be welded should be clean and entirely free from grease.

3. Use a flux-coated REZISTAL filler rod of the proper grade. The flux used on the REZISTAL rod contains no carbonaceous compound, which assures no carbon pickup in the weld deposit.

4. The flux is compounded so that it will clean the weld puddle and escape to the surface carry-

ing along the impurities in the weld. It then forms a glassy film over the deposited metal. By using a short arc the operator can get the most efficient performance from these fluxes. They also reduce the porosity of the weld.

5. After using all of one filler rod, the deposited metal where the weld has stopped will be in the form of a crater. This crater should be cleaned of the flux which envelops it before starting a new rod. Unless this is done the operator will have difficulty in picking up the old weld and may have a porous spot at every junction.

6. When welding sheets from the polished side, the heat should be cut to a minimum to prevent the weld deposit from undercutting the sheet. Welding from the polished side is recommended from 14 gauge up to maximum thickness.

## Soldering

REZISTALS can be soldered without difficulty and strong, firm joints produced. The following is the usual practice:

1. Place the piece to be soldered in position. On highly polished surfaces it is sometimes necessary to roughen up the edges to be soldered with sand paper or other non-metallic abrasive in order to insure proper adhesion. Paint the edges with the soldering flux or fluid. This flux may be any of the prepared brands on the market or ordinary uncut muriatic (hydrochloric) acid or muriatic acid cut with zinc.

2. Due to the low heat conductivity of REZISTALS, it is necessary to heat the soldering iron above the temperature required for ordinary soldering. The metal must be brought up to a heat sufficient to accept the solder in a liquid condition.

3. The speed of the soldering operation should be determined by the thickness of the material and the width of the seam. Sufficient heat must be conducted into the base material to allow the solder to flow into the joints. The speed of travel

should be governed so as to be consistent with a perfect joint. Avoid going over the joint a second time.

4. Various solders have been used with success such as one composed of 75 per cent tin and 25 per cent lead. Silver solders are also used to a large extent. A popular one contains 53 per cent Copper, 15 per cent Nickel, 15 per cent Zinc, and 17 per cent Silver. A hard solder, sometimes used, is composed of 38 per cent Copper, 24 per cent Silver, and 38 per cent Zinc.

5. A certain amount of acid is often splashed on other parts of the work. This will have a corrosive action on the sheets. Therefore, it is a good practice to prepare a solution of one (1) part Nitric Acid to three (3) parts water and apply this solution to the soldered joints and other parts of the work where the soldering fluid may have splashed. Allow it to remain for approximately ten minutes, then wash off with clear water. This acts as a passivation and removes all of the acid from the sheets.

## Brazing

6. Brazing is not generally recommended for corrosion resisting steels, as the contact of dissimilar metals tends to set up an electrolytic action

in the presence of an active electrolyte. The brazing materials are more active in this respect than are the solders.

## Shearing

For shearing REZISTALS of Group I, the shear blades should be adjusted more closely than

is the practice on ordinary steels, so as to prevent dragging of the metal between the knives.



CRUCIBLE STEEL COMPANY OF AMERICA



REZISTAL for Bars and Soda Fountains





# CORROSION AND HEAT RESISTING STEELS

## Punching

Except for the steels in Group II, REZISTAL will not snap off or fracture after a certain portion has been cut, as happens in the case of ordinary steel. This metal, therefore, must be cut through-

out its entire thickness. For this reason, a close, neat fit is required between the punch and die, with less than the customary clearances used on ordinary steel.

## Drilling, Tapping, Milling, Machining and Threading

### Important Note

Early in this development it was recognized that any cutting operation was more difficult on REZISTAL than on ordinary steels because of the tendency of the chip to cling to the tip of the cutting tool, and in the case of the steels in Group I, the work hardening effect of the tool on the surface being cut. This has been corrected with the two types that are most frequently machined or threaded. Thus in Group I we have REZISTAL FM188 and in Group II we have

REZISTAL STAINLESS IRON FREE MACHINING 2. These two grades possess excellent drilling, machining and threading properties and are widely used where screw machine work is desired. For more complete details see the special pages on these two grades. REZISTAL STAINLESS IRON FREE MACHINING 2 is comparable to Bessemer Screw Stock in ease of machinability. REZISTAL FM188 machines as well as straight-carbon or low-alloy steels.

## Drilling

All drills should be sharp, and the point of the drill should not be allowed to ride on the metal without cutting.

In the drilling operation in particular, the tool should be as rigid as possible, and as short as possible for the particular job (especially with small diameter drills), to obviate "springing" of the drill. Cutting lips should be ground with rather more back clearance than is used in drilling ordinary steels, and the point of the drill should be thinned. For the purpose of drilling, the job should only be lightly punched, if at all, and the drill fed straight into the work and, as stated before, not allowed to dwell.

The table below shows speeds and feeds for various sized drills:

Diameter of Drill	Revolutions per Minute	Feed per Revolution
1/16"	1500	.001"
1/8"	800	.0025"
1/4"	400	.005"
1/2"	225	.0075"
3/4"	180	.010"
1"	150	.011"

A lubricant consisting of one pound of sulphur to one gallon of lard oil is recommended.

## Tapping

In tapping, the thread swells appreciably, and therefore suitable allowance should be made in selecting the size drill. This swelling is greater with REZISTAL than with ordinary mild steel, so that the drilling size should be slightly larger for this metal.

The following table shows suggested tapping sizes. Best ground thread taps should be used.

Nominal Size Tap	Standard Tapping Hole	Recommended Tapping Hole
#5	#37 .1040 in.	#36 .1065 in.
#1	#17 .1730 in.	4.5 mm. .1770 in.
1/4 in.	3/16 in. .1875 in.	16/64 in. .2031 in.
3/8 in.	19/64 in. .2968 in.	5/16 in. .3125 in.
1/2 in.	13/32 in. .4063 in.	10.5 mm. .4134 in.
3/4 in.	5/8 in. .6250 in.	41/64 in. .6406 in.
1 in.	27/32 in. .8437 in.	55/64 in. .8594 in.

## Milling

Milling REZISTAL presents no difficulty, but again it is strongly advised that everything about the machine and cutter be rigid and that a cutter having from 10 to 15 degrees of undercut be used

and, of course, kept sharp. Milling speeds should be between 50 and 60 feet per minute for average conditions, 70 feet per minute for light cuts.

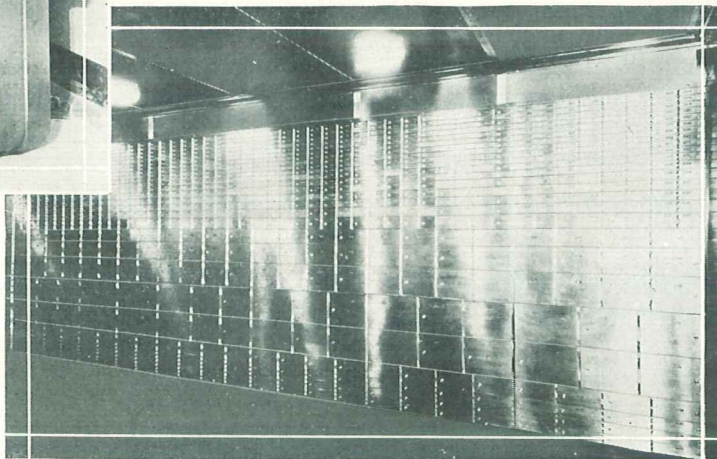
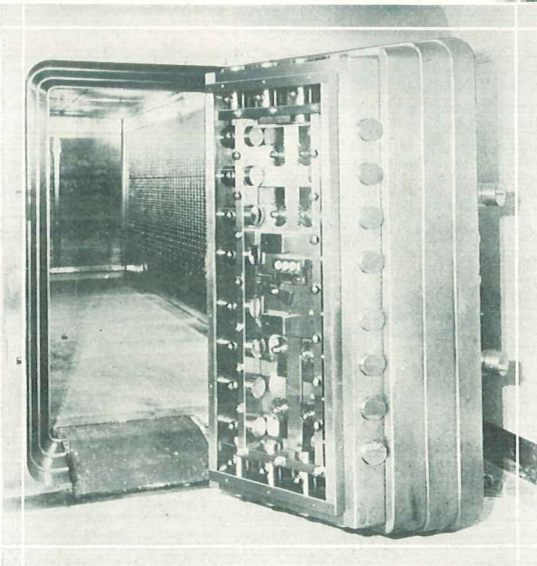
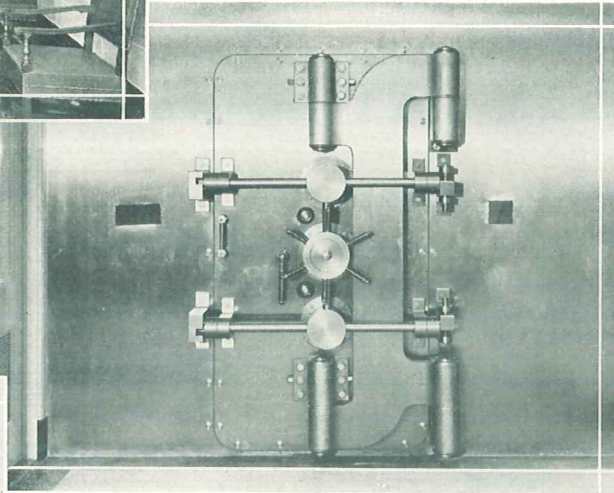
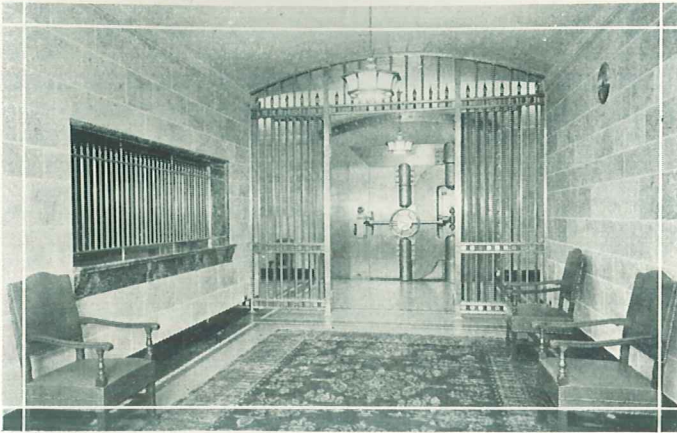
## Sawing

For sawing REZISTALS a high-speed blade should be used, and the speed should not exceed that recommended by the manufacturer (normally 90-100 strokes per minute). In starting the sawing operation make sure that the saw teeth immediately bite into the metal with as little prelim-

inary rubbing as possible. If the saw slides over the surface of the metal, the REZISTALS of Group I will tend to work harden at that point, making further cutting difficult. In selecting high-speed saws for this work, it is recommended that a saw set with ample rake to the teeth be used.



# CRUCIBLE STEEL COMPANY OF AMERICA



REZISTAL for Bank Vaults and Safe Deposit Boxes

# CORROSION AND HEAT RESISTING STEELS

## Machining

As mentioned before, REZISTAL STAINLESS IRON FREE MACHINING 2, or REZISTAL FM188, should be used on those applications where considerable machining is necessary and where the corrosive conditions are such to allow their use. With REZISTAL STAINLESS IRON FREE MACHINING 2, feeds and speeds similar to those used on Bessemer Screw Stock can be employed. On REZISTAL FM188, slightly slower speeds are necessary. In all cases, the tool should be ground sharp and kept sharp, with a steep lip and side rake of at least 15 degrees. The use of a cutting compound is recommended. A good compound is a mixture of 1 gallon of lard oil with 1 pound of sulphur. Slight modifications as regards the shape of tools, feeds, speeds, etc., as

outlined below, are necessary on all types except REZISTAL STAINLESS IRON FREE MACHINING 2.

Outside of the free machining types roughing speeds of 30 to 60 feet per minute are generally employed. The machines and tools used should be rigid and free from back lash. The tools should be of REX AA, REX 95, or some other good high-speed steel. In turning REZISTAL, attention should be paid to the tightness of the job between the centers, slacking back being necessary to allow for expansion due to heating. This is necessary owing to the higher coefficient of expansion of these steels as compared with ordinary steel.

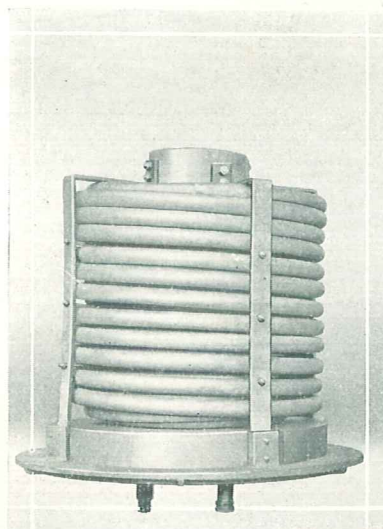
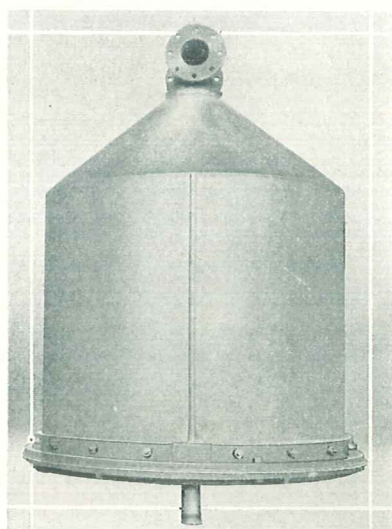
The following table gives details of speeds, feeds, tool angles, etc., for roughing and turning:

	LIGHT WORK		HEAVY WORK		EXTRA HEAVY WORK	
	Rough turning	Finish turning	Rough turning	Finish turning	Rough turning	Finish turning
Cutting speed ft. per min. ....	30/50	40/100	45	40/60	16	16
Depth of cut, inches.....	1/16	.002/.003	3/16	.004	3/4	3/16
Feed, inches .....	1/36	1/48	1/40 to 1/16	1/48 to 1/80	1/40	1/48
Cutting angles:—						
Front rake .....	10/20°	15/20°	10/20°	15/20°	10/12°	12/14°
Side rake .....	10/15°	0/5°	10/15°	0/5°	8/10°	10/12°
Front Clearance .....	5/10°	5/10°	5/10°	5/10°	12/14°	14/16°
Side Clearance .....	5/10°	5/10°	5/10°	5/10°	6/8°	8/10°

## Threading

In threading REZISTAL a four to five thread lead should be used instead of the customary two or three thread lead and the same lubricant should

be used as recommended under the heading of machining.



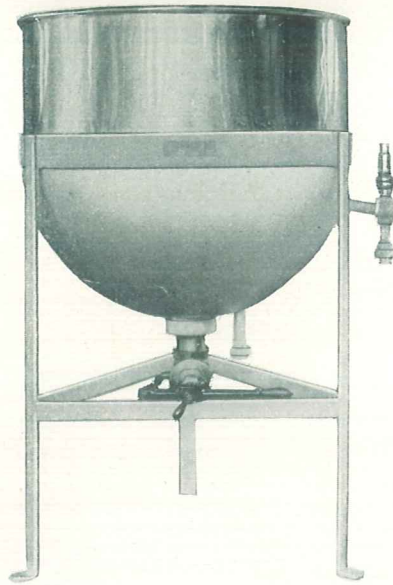
REZISTAL Acid Coolers



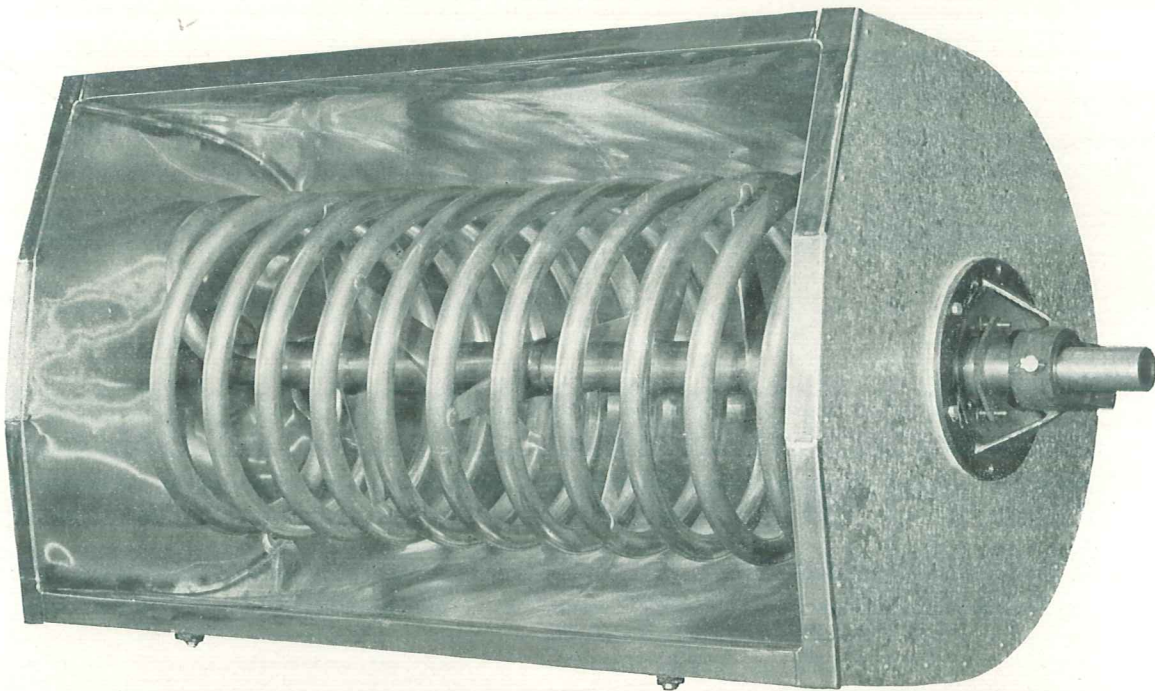
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CRUCIBLE STEEL COMPANY OF AMERICA

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REZISTAL Steam Jacketed Kettle



Interior of Twin Coil Pasteurizer made of REZISTAL

## **THE REZISTAL KA2 FAMILY**



The most popular member of the KA2 family, serving a wide variety of purposes. Carbon .08 to .20, Chromium 17.00 to 19.00, Nickel 7.00 to 9.50.

Slightly better drawing qualities than REZISTAL KA2, also is free from susceptibility to intergranular corrosion after welding in the presence of weak electrolytes. Carbon .07 max., Chromium 17.00 to 19.00, Nickel 7.00 to 9.50.

A special free machining variety recommended for those applications requiring extensive machining. Carbon .08 to .20, Chromium 17.00 to 19.00, Nickel 7.00 to 9.50, Phosphorus .10 max., Sulphur .15 min., Molybdenum or Selenium optional.

A special type, slightly higher in chromium and nickel, preferred by the Navy Department and others. Carbon .08 to .20, Chromium 18.00 to 20.00, Nickel 8.00 to 10.00.

A special type, slightly higher in chromium and nickel, preferred by the Navy Department and others. Carbon .07 max., Chromium 18.00 to 20.00, Nickel 8.00 to 10.00.

A special analysis, seldom called for, but available on request. Carbon .08 to .20, Chromium 19.00 to 22.00, Nickel 9.00 to 12.00.

A special analysis made in accordance with Navy specification 47S20A and 46S18B. Carbon .07 max., Chromium 19.00 to 22.00, Nickel 9.00 to 12.00.

A special analysis free from susceptibility to intergranular corrosion after welding in the presence of moderate and strong electrolytes. Carbon .07 max., Chromium 17.00 to 19.00, Nickel 7.00 to 9.00, Titanium .35 min.

Similar to REZISTAL KA2ST except that it is higher in minimum chromium and nickel content. Carbon .07 max., Chromium 18.00 to 20.00, Nickel 7.00 to 10.00, Titanium 6 × Carbon.

The heat-resisting member of the REZISTAL KA2 family, is used for resistance to scaling up to 1700°F. Carbon .08 to .20, Chromium 17.00 to 19.00, Nickel 7.00 to 9.50, Silicon 2.00 to 3.00.

A steel more resistant to general corrosion than REZISTAL KA2, is strongly resistant to intergranular corrosion and possessing the highest strength and resistant to creep at temperatures up to 1600°F. Carbon .07 max., Chromium 16.00 to 19.00, Nickel 14.00 max., Molybdenum 2.00 to 4.00.

**REZISTAL KA2 (Type 302)**

**REZISTAL KA2S (Type 304)**

**REZISTAL FM188 (Type 303)**

**REZISTAL KA2-199 (Type 305)**

**REZISTAL KA2S-199 (Type 306)**

**REZISTAL KA2-2010 (Type 307)**

**REZISTAL KA2S-2010 (Type 308)**

**REZISTAL KA2ST (Type 320)**

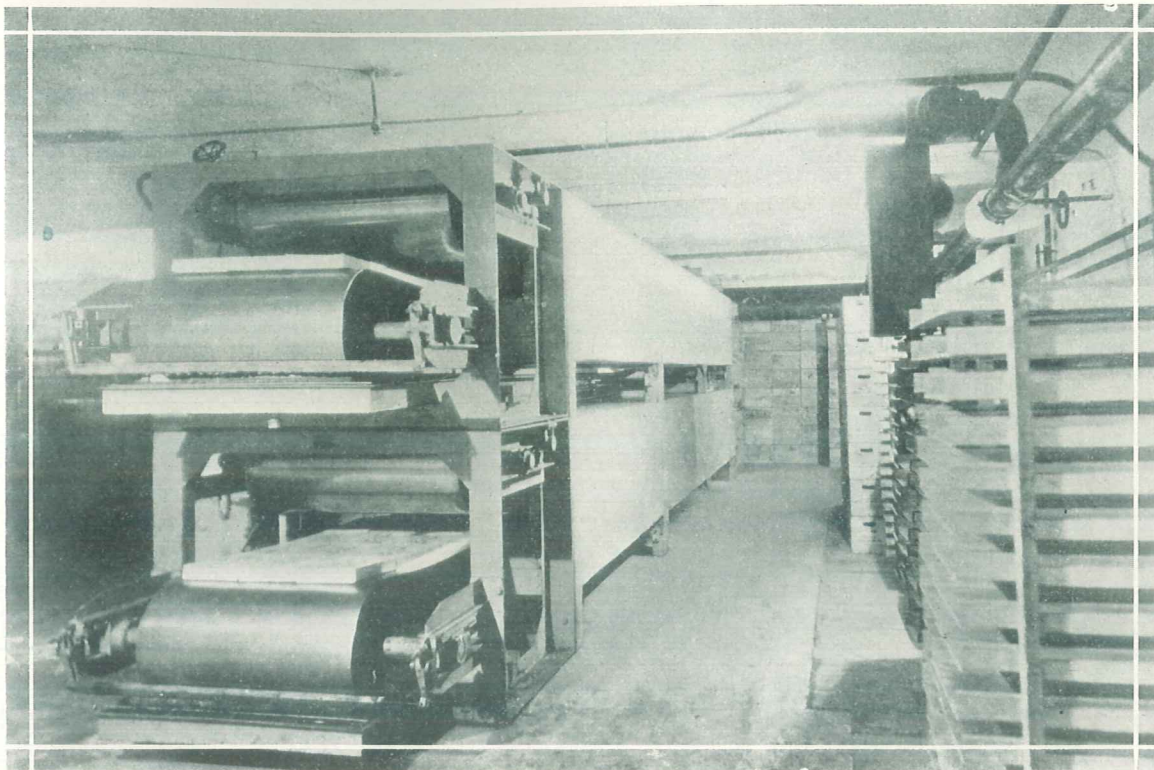
**REZISTAL KA2ST Special (Type 321)**

**REZISTAL 2C (Type 302B)**

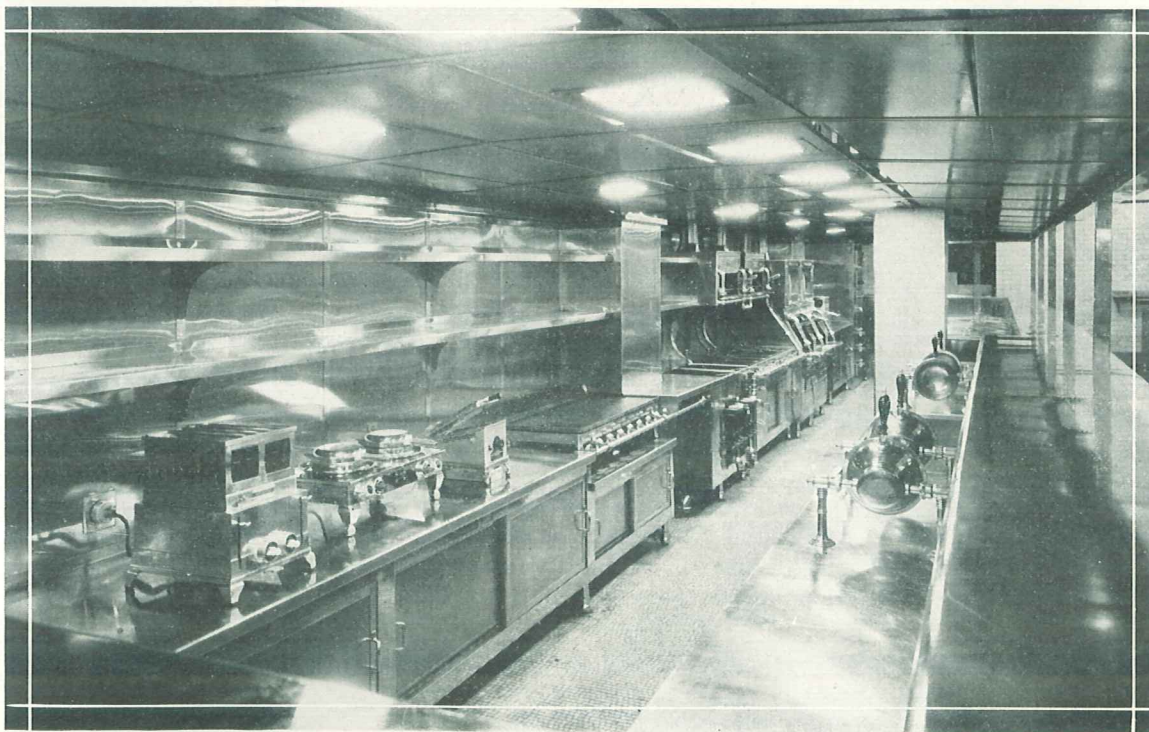
**REZISTAL KA2SMO (Type 316)**



# CRUCIBLE STEEL COMPANY OF AMERICA



Above: Fish Frosting Belt of REZISTAL  
Below: Short Order Counter of REZISTAL





# CORROSION AND HEAT RESISTING STEELS

## REZISTAL KA2

Non-hardenable Austenitic Chromium Nickel Steel of Group I

REZISTAL KA2 (with its modifications) is to be considered the GENERAL PURPOSE corrosion-resisting steel. Slight modifications in analysis and mill practice also adapt it to many special purposes. For example, REZISTAL FM188 is the free machining variety, REZISTAL KA2S and REZISTAL KA2ST are resistant to intergranular corrosion after welding, and REZISTAL 2C is the scale-resisting member of the family. The physical properties are approximately the same for all these types.

REZISTAL KA2 (with its modifications) is resistant to a very large variety of corrosive media and possesses excellent forming, welding and general fabricating characteristics combined with high strength and excellent ductility. It is therefore the type most generally used for architectural trim; for kitchen, restaurant and cafeteria equipment; for the various units of dairy and milk-handling equipment; for trays, decanters and other household

novelties. Its use in the chemical industry is widespread as is its application for textile and dyeing equipment vats. The petroleum industry uses large quantities of this grade as well as other REZISTALS.

For spinning or severe deep drawing a special modification known as REZISTAL KA2SFS has been developed. See page 41 for more details on this type.

REZISTAL KA2 (and its modifications) is Austenitic in character and hence non-magnetic. This grade cannot be hardened by heat treatment but the tensile strength and hardness can be materially increased by cold work. Hence it is possible to secure cold rolled strip with a tensile strength up to 200,000 lbs. per square inch and cold drawn wire with a tensile strength up to 250,000 lbs. per square inch.

If resistance to wear or abrasion is a factor see remarks under abrasion on page 15.

### Physical Properties, Annealed

Tensile Strength .....	85,000 to 95,000	Specific Electrical Resistance (microhms per cu. cm.)	
Yield Point .....	30,000 to 40,000	20 deg. C.	73
Elongation in 2" .....	55 to 60%	100 deg. C.	90
Reduction of Area .....	65 to 75%	500 deg. C.	106
Brinell .....	130 to 170	800 deg. C.	111
Charpy .....	100	Coefficient of Linear Expansion (per deg. C.)	
Thermal Conductivity (gram-calories per cu. cm. per sec. per deg. C.)	0.052	0 to 100 deg. C.	0.000016
Specific Gravity .....	7.94	0 to 600 deg. C.	0.000018
Specific Heat .....	0.118	0 to 1,000 deg. C.	0.000020
Melting Point, deg. F. ....	2,550	Modulus of Elasticity .....	28,000,000 to 30,000,000

### Electrolysis

In contact with dissimilar metals, in the presence of some electrolytes, there may be set up an electrolytic action between the two materials. The following lists give the results of tests made on REZISTAL KA2 in contact with other metals in SALT WATER.

These tests indicate that REZISTAL KA2 cannot be used in contact with the following in salt water:

Monel Metal  
Rubber Asbestos Packing  
Any packing material containing sulphur

The following materials do not affect REZISTAL KA2, and their own rates of corrosion

are not materially affected by contact with REZISTAL KA2 in salt water:

Copper	Phosphor Bronze
Graphite	Manganese Bronze
Brass	Hytensil Bronze
Tobin Bronze	Cast Iron
Aluminum Bronze	SAE-1020

The following do not affect REZISTAL KA2, but their own rates of corrosion are appreciably accelerated by contact with REZISTAL KA2 in salt water:

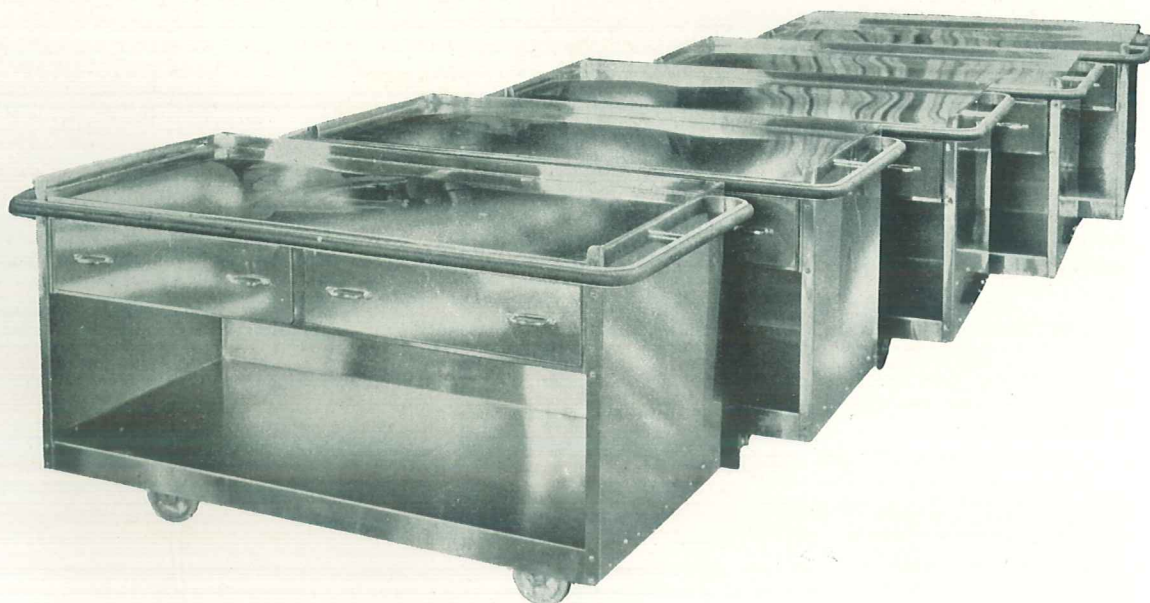
Aluminum	REZISTAL STAINLESS 12
Lead	REZISTAL STAINLESS 17
Babbitt Metal	



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Portable Ice Cream Tables of REZISTAL

Hospital Steam Food Cooking Equipment of REZISTAL





## CORROSION AND HEAT RESISTING STEELS

### Fabrication

For complete details see pages 19 to 31.

**Forging:** Should be started at 2150° to 2200°F., and should be finished above 1500°F. See page 19 for further instructions.

**Upsetting:** Should be done at such a temperature so as to finish between 1700° and 1800°F.

**Annealing:** For maximum softness anneal at 2000°F. Parts fabricated from sheets or light plates may be air cooled while heavy parts should be water quenched. Final anneal to relieve fabricating strains and produce best corrosion and heat resisting properties should be at a temperature not over 1900°F.

**Forming:** This grade can be very easily formed to most desired shapes.

**Drawing and Spinning:** The easiest drawing

and spinning grade of the REZISTAL family. See page 41 for special free spinning type.

**Machining:** Is commercially possible with REZISTAL KA2, but REZISTAL FM188 is best for use on all applications where considerable machining is contemplated.

**Welding:** See note on intergranular corrosion on page 15 as well as welding instructions on page 25.

**Riveting:** While there is no difficulty in riveting KA2, the special welding characteristics make welding the preferred method. When riveting is used it should be carried out at 1900°F.

**Pickling:** See page 19.

**Polishing and Buffing:** See page 23.

**Brazing and Soldering:** See page 27.

### In Non-Skid Floor Plates

We have for several years been making a diamondette pattern non-skid floor plate of REZISTAL KA2. This has found considerable application in Navy and commercial vessels where a corrosion resisting and non-skid floor surface was desired. It has also been used with considerable success for stair treads. Recently the use of this

material has spread to uses in buildings where a non-skid flooring or stair tread with corrosion-resisting properties is desired.

This material can be furnished with a solid back with a raised diamond surface or can be furnished with a slightly indented back with a raised diamond surface in certain gauges.



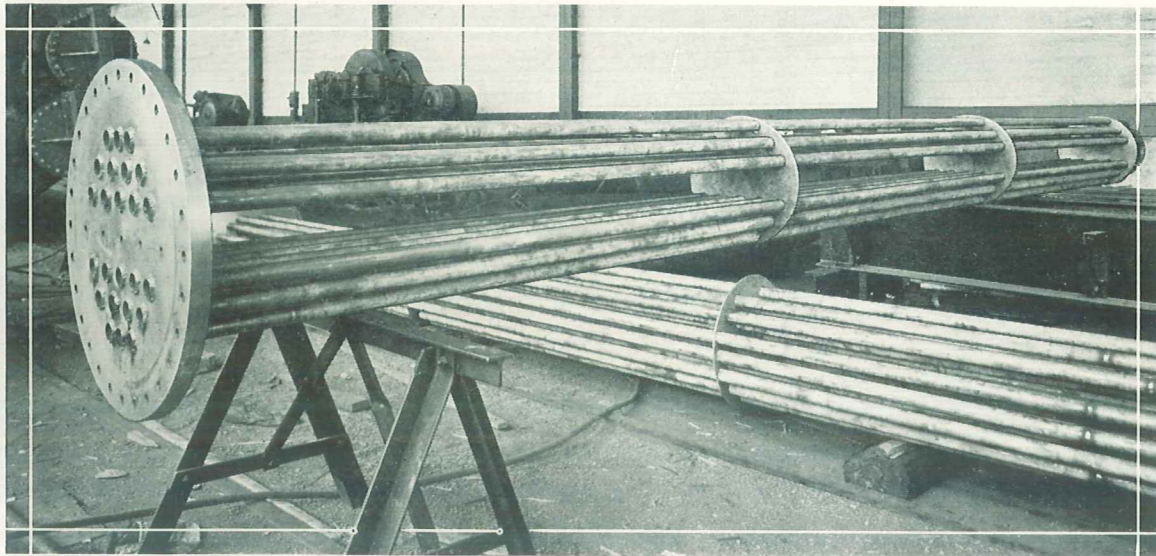
Non-skid Floor Plate of Diamondette Pattern of REZISTAL KA2



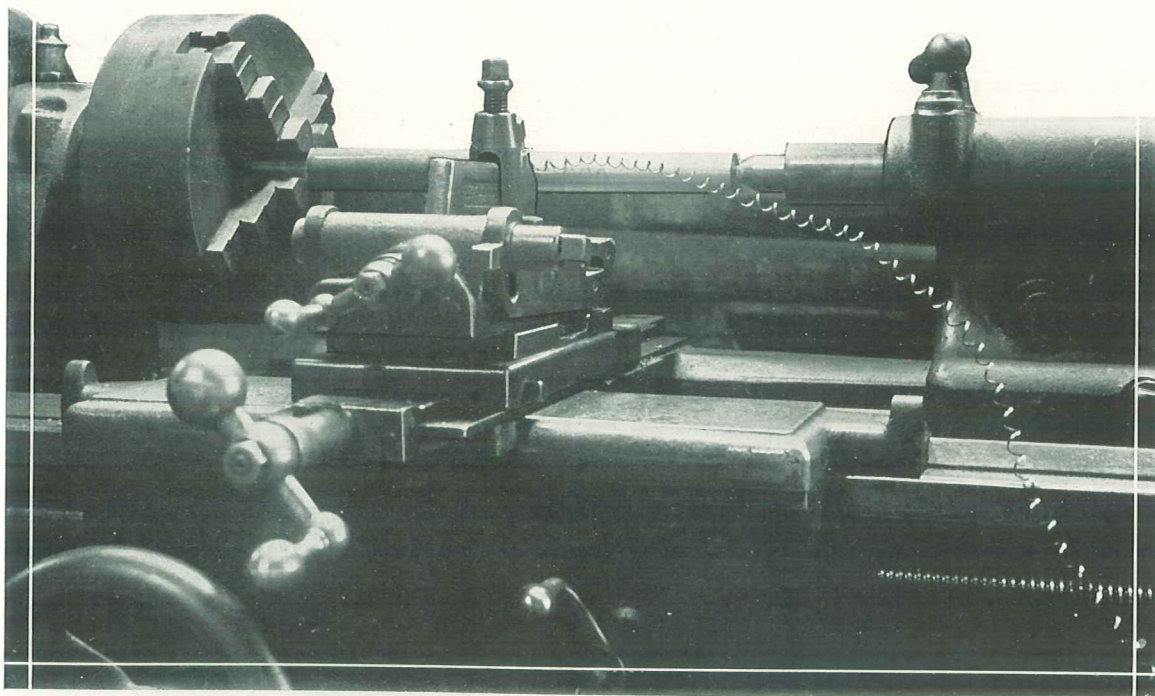
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Acetic Acid Coils of REZISTAL KA2S



Typical Chip when Machining REZISTAL FM188

## **REZISTAL KA2S and KA2ST**

Non-hardenable Austenitic Chromium Nickel Steel of Group I



As mentioned under REZISTAL KA2, when it is impossible to anneal after welding or when the fabricated article is to be subjected to heats in the dangerous 1000° to 1500°F. range, it is necessary to use either REZISTAL KA2S or REZISTAL KA2ST. The choice between these two

grades depends upon the severity of the electrolyte or corroding medium. For less severe applications REZISTAL KA2S may be satisfactory but for more severe applications it is imperative to use REZISTAL KA2ST to avoid susceptibility to intergranular corrosion.

### **Composition**

The chemical composition of REZISTAL KA2S is approximately the same as REZISTAL KA2 except that the carbon is kept below .07.

The chemical composition of REZISTAL

KA2ST is approximately the same as REZISTAL KA2S except that titanium in a quantity equal to at least six times the carbon content is added to eliminate susceptibility to intergranular corrosion.

### **Corrosion Resistance**

The general corrosion resistance of these two grades is practically the same as REZISTAL KA2. However, extensive tests have shown that the resistance of welded REZISTAL KA2ST in

Nitric Acid is superior to that of REZISTAL KA2 and this superiority should hold for many other corroding media.

### **Fabrication**

**Polishing:** REZISTAL KA2S can be polished to the same high finish as REZISTAL KA2. REZISTAL KA2ST can be polished, but a high lustre finish is not possible as the surface will have a slightly cloudy appearance and therefore it is not recommended for decorative purposes.

**Welding:** As mentioned above, these two grades are recommended where it is not possible to anneal after welding. REZISTAL KA2S welding rod should be used on both of these grades

except when the fabricated article is to be used within the dangerous temperature range of 1000° to 1500°F., in which case REZISTAL KA2SMO welding rod should be used. If a REZISTAL KA2ST welding rod is used, most of the titanium is lost in the melting of the rod.

**Physical, Mechanical, Working, Fabricating and other properties, outside of resistance to intergranular corrosion, are the same as those of REZISTAL KA2.**

## **REZISTAL FM188**

Non-Hardenable Austenitic Chromium Nickel Steel of Group I

This grade was developed to meet the requirements for a material equal in strength, resistance to corrosion, and other properties of REZISTAL KA2, except that it offers greater ease in machining and superior non-seizing properties. REZISTAL FM188 has had wide application for

screw machine products and larger articles where considerable or delicate machining is to be done.

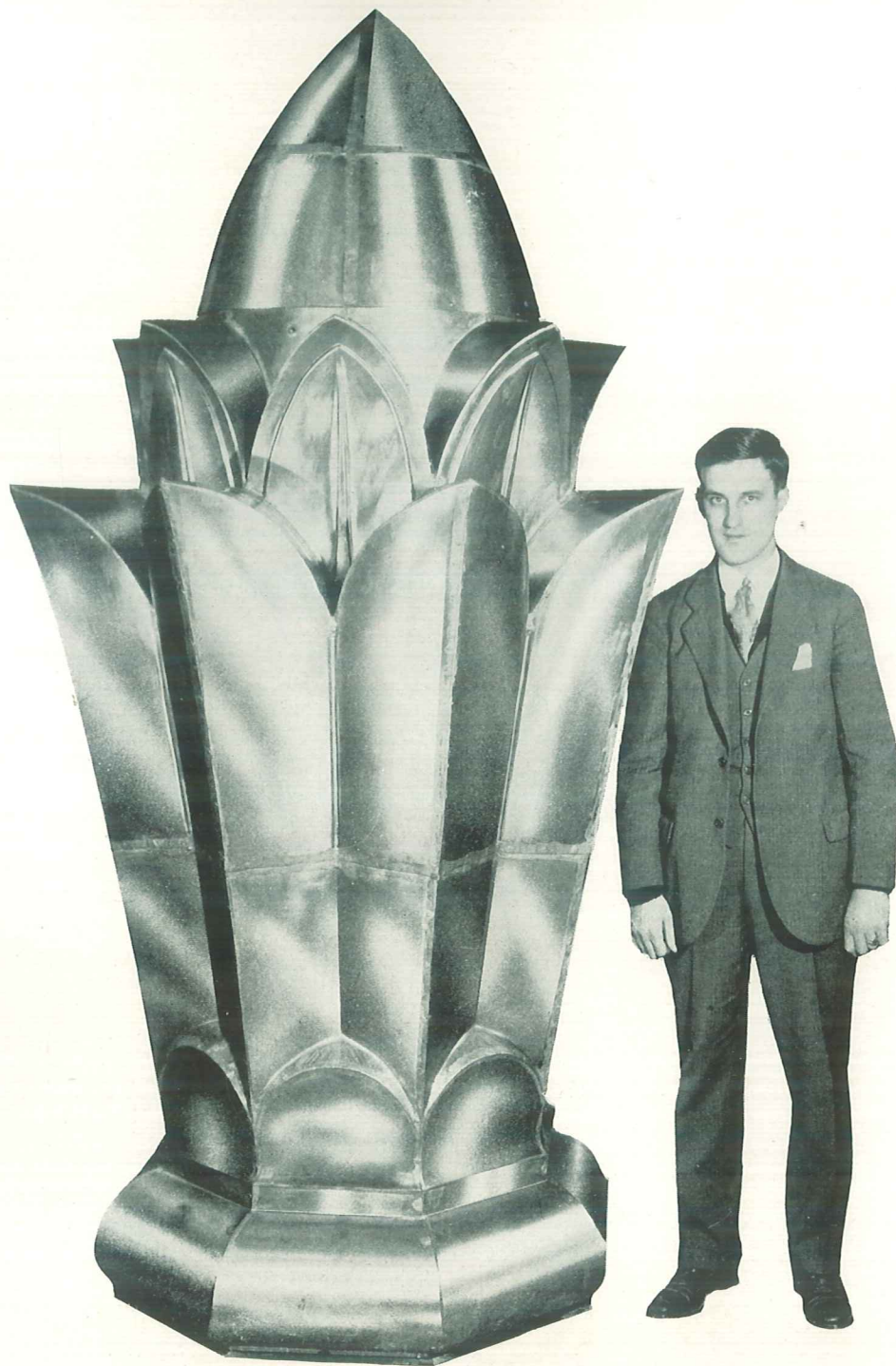
The resistance to corrosion, physical properties and fabricating properties, with the exception of machinability, are the same as REZISTAL KA2.



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Typical Fabrication of REZISTAL KA2 for Architectural Trim

## REZISTAL KA2SFS

Non-hardenable Austenitic Chromium Nickel Steel of Group I

REZISTAL KA2S has always been well considered as steel for spinning. However the need for a more free spinning type of corrosion resisting steel was recognized. After considerable research, we developed an analysis so balanced, a manufacturing process so closely controlled, and a heat treating operation so regulated as to give a material that would retard the breakdown of Austenite into Martensite on cold working.

We now offer REZISTAL KA2SFS as the outstanding spinning steel in the entire field of corro-

sion resisting steels. This material has made possible the spinning of intricate shapes heretofore unheard of with these steels. The deep drawing properties of this particular grade are also superior to those of any other type of corrosion resistant steels.

While it is still necessary to resort to intermediate anneals on severely spun or severely drawn articles, considerably more work can be done before the intermediate anneal is necessary and fewer intermediate anneals will be required.

### Fabrication

**Annealing:** The intermediate anneals should consist of heating the article to 2000°F., for sufficient length of time to insure thorough penetration of the heat and cooling in air. Care, of course, should be taken to see that the heating is done in an atmosphere that will not produce a carbon pick-

up on the surface or an appreciable amount of scaling.

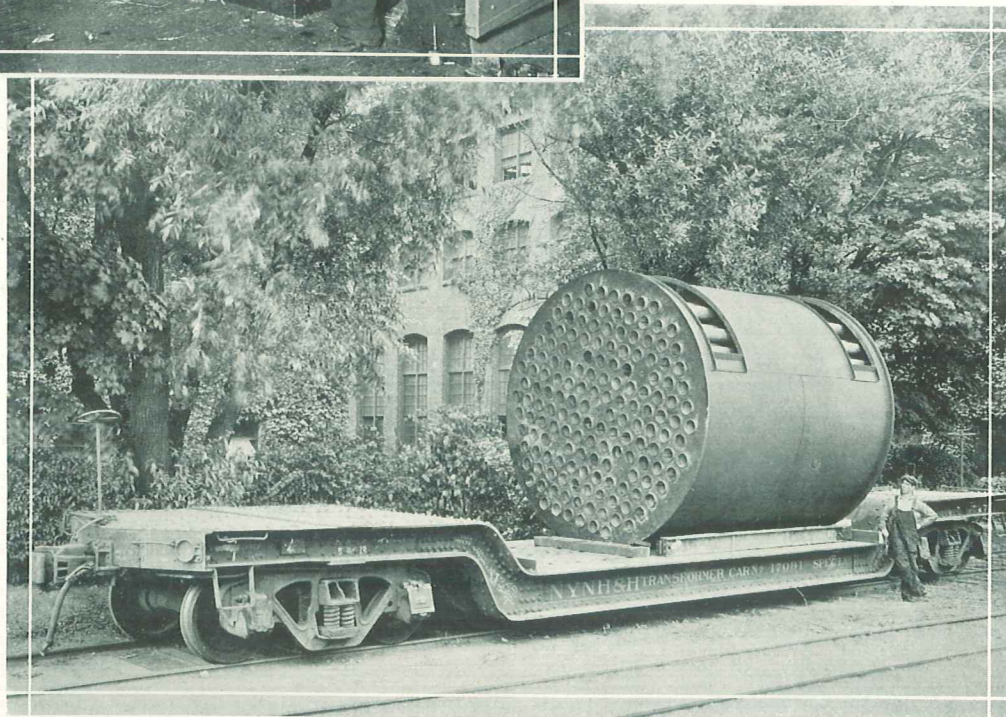
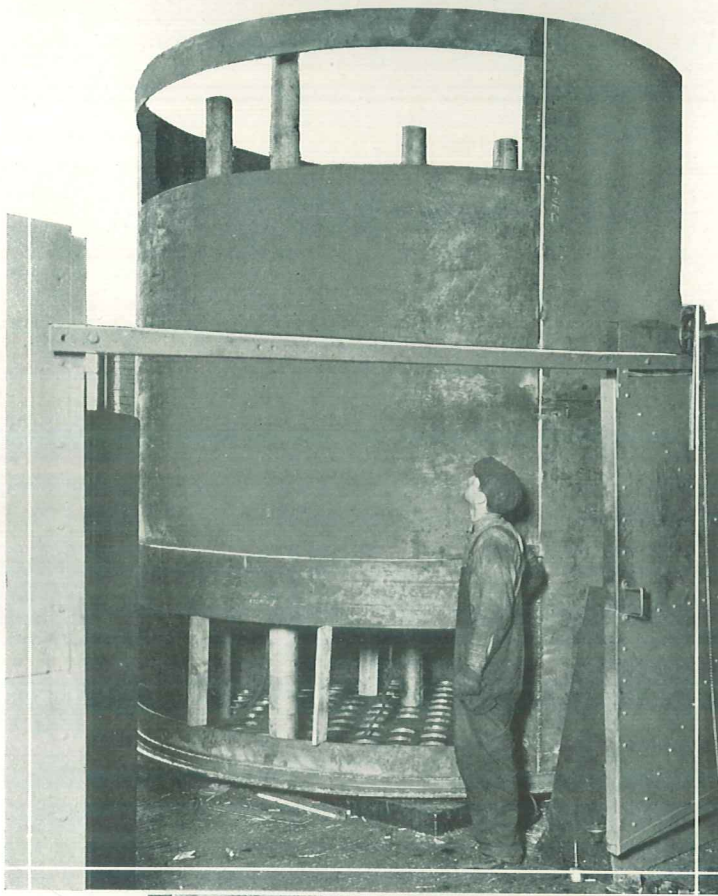
Other Physical and Fabricating Properties and Pickling Treatments are the same as those of REZISTAL KA2.



A spun Coffee Urn Top of REZISTAL KA2SFS



CRUCIBLE STEEL COMPANY OF AMERICA



Air preheaters made of REZISTAL 2C



# CORROSION AND HEAT RESISTING STEELS

## REZISTAL 2C

Non-hardenable Austenitic Chromium Nickel Steel of Group I  
Carbon .08 to .20, Chromium 17.00 to 19.00, Nickel 7.00 to 9.50, Silicon 2.00 to 3.00

REZISTAL 2C is an alloy of the REZISTAL KA2 type with the exception of a higher Silicon content. This higher Silicon content greatly improves the resistance to scaling and REZISTAL 2C is to be considered the scale resistant member of the REZISTAL KA2 family. Scaling is a function of atmosphere as well as of temperature and it is difficult therefore to state the upper limit

of non-scaling properties without knowing precisely the atmosphere to be encountered. For many applications REZISTAL 2C has been found to satisfactorily withstand scaling up to 1700°F.

REZISTAL 2C has had wide application in air preheaters, furnace parts, range oil burner shells, and many other applications where the upper limit of operating temperature is 1700°F., or below.

### Physical Properties, Annealed

Tensile Strength .....	90,000 to 100,000	Specific Gravity .....	7.77
Yield Point .....	40,000 to 50,000	Coefficient of Linear Expansion (per deg. C.)	
Elongation in 2" .....	50 to 60%	0 to 100 deg. C.	0.000016
Reduction of Area .....	50 to 70%	0 to 600 deg. C.	0.000018
Brinell .....	140 to 180	0 to 1,000 deg. C.	0.000020
Charpy .....	100	Modulus of Elasticity .....	28,000,000 to 30,000,000

### Fabrication

For complete details see pages 19 to 31.

**Forging:** Should be started at 2100° to 2150°F., and should be finished not lower than 1500°F.

**Upsetting:** Should be done at a temperature so as to finish between 1700° and 1800°F.

**Annealing:** For maximum softness anneal at 2000°F. Parts fabricated from sheets or light plates may be air cooled while heavy parts should be water quenched. Final anneal, to relieve fabricating strains, between 1850° and 1900°F. For best heat resisting properties, anneal at a temperature not over 1650°F., for two to four hours and furnace or air cool. If the material has previously been annealed at a higher temperature, the time of annealing at 1600° to 1650°F. may be prolonged.

**Forming:** This grade is slightly harder to form than REZISTAL KA2.

**Drawing and Spinning:** Can be drawn, but spinning is not recommended.

**Machining:** This grade can be commercially machined.

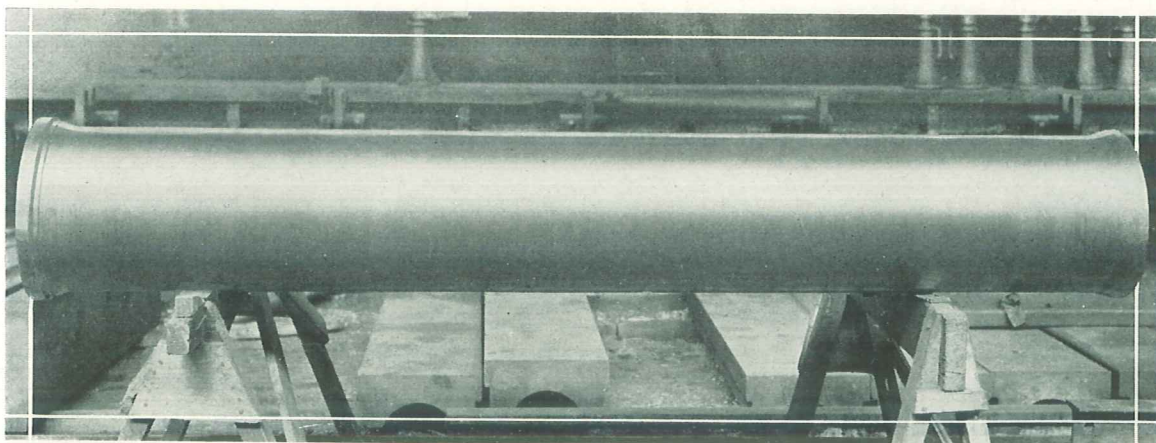
**Welding:** Is an excellent welding material.

**Riveting:** While there is no difficulty in riveting REZISTAL 2C, the special welding characteristics make welding the preferred method. When riveting is used it should be carried out at 1950°F.

**Pickling:** See page 19.

**Polishing and Buffing:** See page 23.

**Brazing and Soldering:** See page 27.



REZISTAL 2C Liner for Pressure Still, Machined Inside and Outside



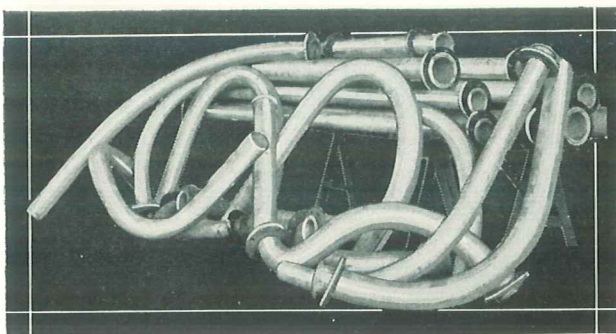
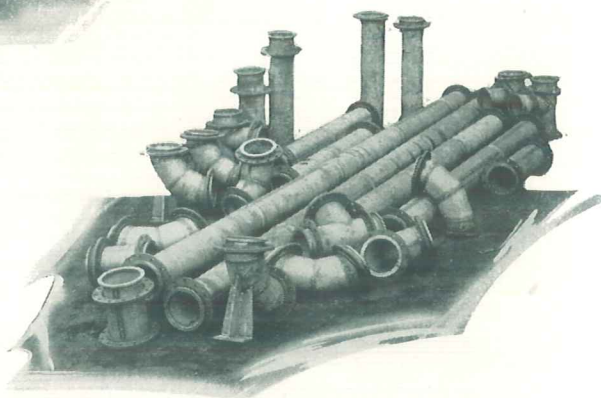
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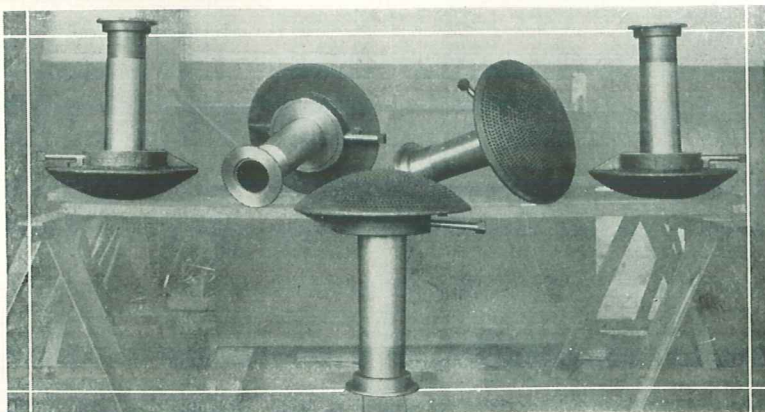
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REZISTAL KA2SMO Hemispherical  
Kettles for the Chemical Industry,  
jacketed and polished on the inside



REZISTAL KA2SMO Piping and  
Digester Strainers for the Paper  
Industry



## REZISTAL KA2SMO

Non-hardenable Austenitic Chromium Nickel Steel of Group I

Carbon .07 max., Chromium 16.00 to 19.00, Nickel 14.00 max., Molybdenum 2.00 to 4.00

REZISTAL KA2SMO is an alloy even better in resistance to corrosion than REZISTAL KA2. There are some applications where REZISTAL KA2 is satisfactory under normal pressure and temperatures, but when the temperature and pressure are increased, it is sometimes necessary to use REZISTAL KA2SMO for complete resistance. This is particularly true with the hot sulphite liquors and bleaches encountered in the paper pulp industry. REZISTAL KA2SMO has been found

satisfactory for the high concentrations of Acetic, Phosphoric, Tartaric, and similar acids. For detailed results of corrosion tests see Corrosion Tables beginning on page 5.

REZISTAL KA2SMO is resistant to susceptibility to intergranular corrosion. Therefore it can be used for those welded applications which cannot be annealed after welding. It is recommended for those applications which involve long exposure within the 1000° to 1500°F. range.

### Creep Resistance and Strength at Elevated Temperatures

Molybdenum, when added to alloys of the 18-8 series, such as REZISTAL KA2, imparts high strength at elevated temperatures and high creep strength. REZISTAL KA2SMO has been found

to possess the greatest resistance to creep of any of the corrosion and heat resisting steels; and is the grade to be used when maximum resistance to creep up to 1600°F. is desired.

### Physical Properties, Annealed

Tensile Strength .....	90,000 to 100,000	Thermal Conductivity (gram-calories per	
Yield Point .....	40,000 to 50,000	cu. cm. per sec. per deg. C.) .....	0.052
Elongation in 2" .....	50 to 60%	Coefficient of Linear Expansion (per deg. C.)	
Reduction of Area .....	60 to 75%	0 to 100 deg. C.	0.000016
Brinell .....	170 to 200	0 to 600 deg. C.	0.000018
Charpy .....	100	0 to 1,000 deg. C.	0.000020
Specific Gravity .....	7.91	Modulus of Elasticity .....	28,000,000 to 30,000,000

### Fabrication

For complete details see pages 19 to 31.

**Forging:** Should be started at 2100° to 2150°F., and should be finished at about 1700°F.

**Upsetting:** Should be done at such a temperature so as to finish at between 1700° and 1800°F.

**Annealing:** For maximum softness anneal at 2100°F. Parts fabricated from sheets or light plates may be air cooled while heavy parts should be water quenched. Final anneal to relieve fabricating strains and produce best corrosion resistance, should be at a temperature not over 1900°F. For strength at elevated temperature two to four hours at 1650°F., followed by a furnace or air cool, is recommended.

**Forming:** This grade can be readily formed, but works harder than REZISTAL KA2.

**Drawing and Spinning:** Can be drawn, but spinning is not recommended.

**Machining:** This grade can be commercially machined.

**Welding:** An excellent welding material.

**Riveting:** While there is no difficulty in riveting REZISTAL KA2SMO, the splendid welding characteristics make welding the preferred method. When riveting is used it should be carried out at 1950°F.

**Pickling:** See page 19.

**Polishing and Buffing:** See page 23.

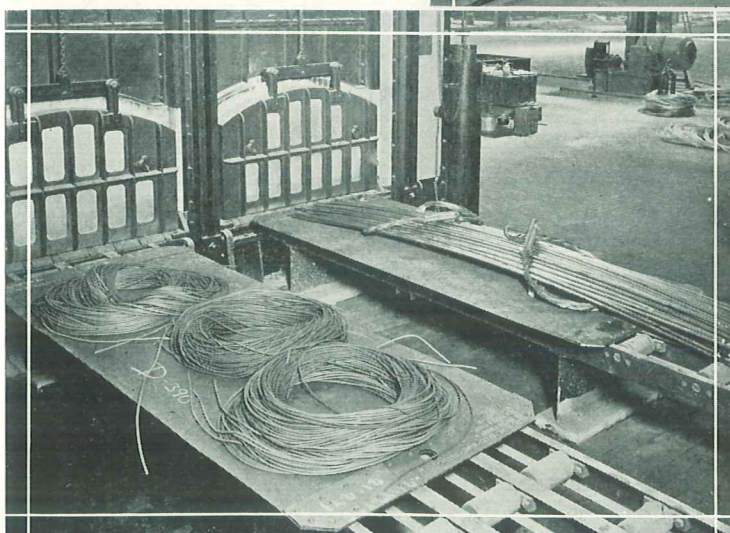
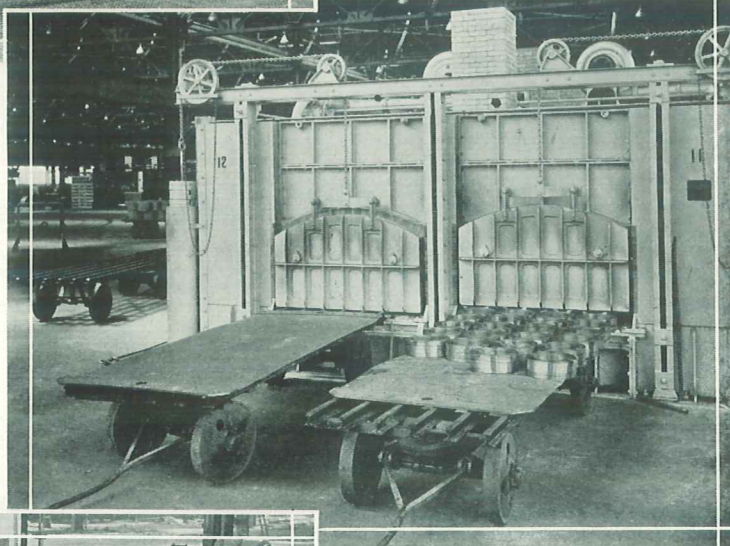
**Brazing and Soldering:** See page 27.



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Annealing Pans

REZISTAL 3, REZISTAL 2C and REZISTAL Stainless Iron 17 are used for such applications



# CORROSION AND HEAT RESISTING STEELS

## REZISTAL 3 and 3C

Non-hardenable Austenitic Chromium Nickel Steel of Group I

REZISTAL 3: Carbon .20 max., Chromium 22.00 to 26.00, Nickel 12.00 to 14.00

REZISTAL 3C: Carbon .20 max., Chromium 22.00 to 26.00, Nickel 12.00 to 14.00, Silicon 2.00 to 3.00

These two steels of our corrosion and heat resistant steel family possess increased resistance to scaling at elevated temperatures. The increased Chromium, Nickel, and Silicon content also add somewhat to their resistance to corrosion in certain media. These steels are considered second to only REZISTAL KA2SMO for resistance to sulphite liquors; but are not recommended for

welded parts unless annealing after welding is possible.

REZISTALS 3 and 3C have had many successful applications for heat and scale resistance. They have been used as baffles in air preheaters, for various parts of automatic heat treating equipment and many other applications.

See page 17 for the proper choice of heat resisting steels.

### Physical Properties, Annealed

Tensile Strength	95,000 to 105,000	Specific Electrical Resistance (microhms per cu. cm.)	
Yield Point	40,000 to 50,000	At room temperature	80
Elongation in 2"	40%	700 deg. C.	117
Reduction of Area	50%	Coefficient of Linear Expansion (per deg. C.)	
Brinell	170 to 200	0 to 100 deg. C.	0.000016
Charpy	80	0 to 600 deg. C.	0.000018
Thermal Conductivity (gram-calories per cu. cm. per sec. per deg. C.)	0.039	0 to 1,000 deg. C.	0.000020
		Modulus of Elasticity	28,000,000 to 30,000,000

### Resistance to Scaling

REZISTAL 3C has slightly better resistance to scaling than REZISTAL 3 because of its additional silicon content. However its fabricating properties are somewhat more difficult. Therefore

for intricate fabrication REZISTAL 3 is suggested but where a proposed manner of fabrication indicates no difficulty REZISTAL 3C should be used because of its increased scale resisting properties.

### Fabrication

For complete details see pages 19 to 31.

**Forging:** Should be started at 2100° to 2150°F., should be finished at about 1700°F. See page 19.

**Upsetting:** Should be done at a temperature so as to finish between 1700° and 1800°F.

**Annealing:** For maximum softness anneal at 2100°F. Parts fabricated from sheets or light plates may be air cooled while heavy parts should be water quenched. Final anneal to relieve fabricating strains and produce best corrosion and heat resisting properties, should be at a temperature not over 1900°F.

**Forming:** These grades are readily formed, but work somewhat harder than REZISTAL KA2. REZISTAL 3 forms more easily than REZISTAL 3C.

**Drawing and Spinning:** Can be drawn, but spinning should not be attempted.

**Machining:** These grades can be commercially machined. See page 31.

**Welding:** Both are excellent welding materials. See page 25.

**Riveting:** While there is no difficulty in riveting REZISTALS 3 and 3C the splendid welding characteristics make welding the preferred method. When riveting is used it should be carried out at 1950°F.

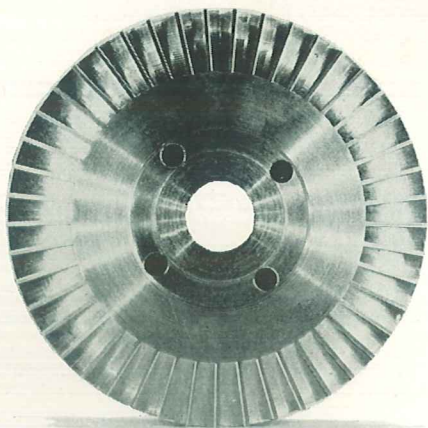
**Pickling:** See page 19.

**Polishing and Buffing:** See page 23.

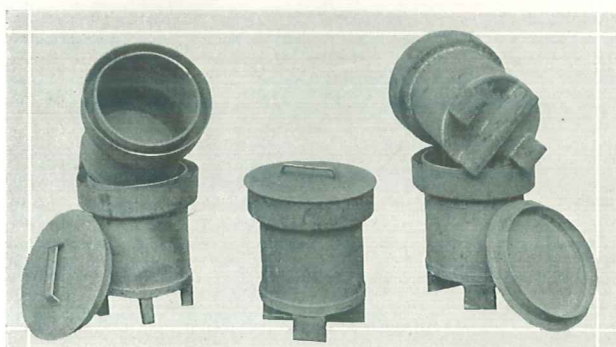
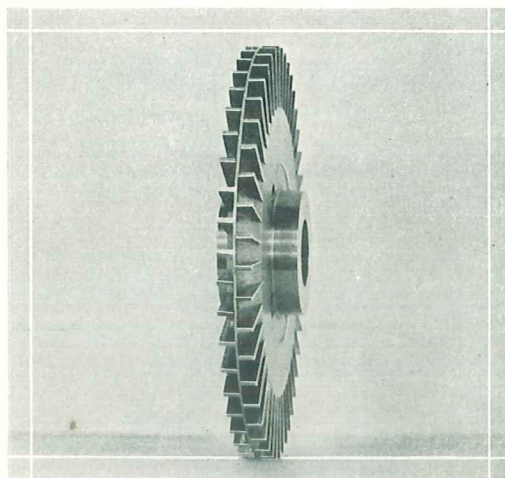
**Brazing and Soldering:** See page 27.



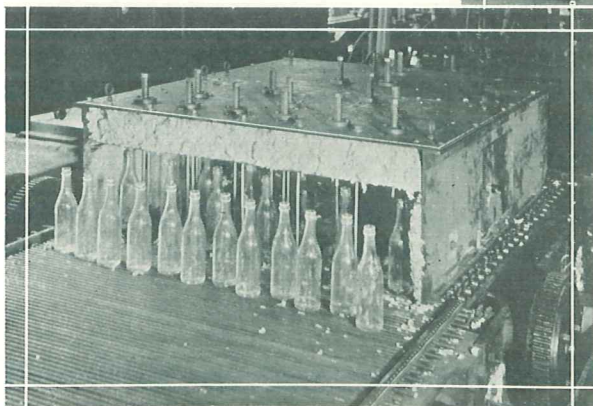
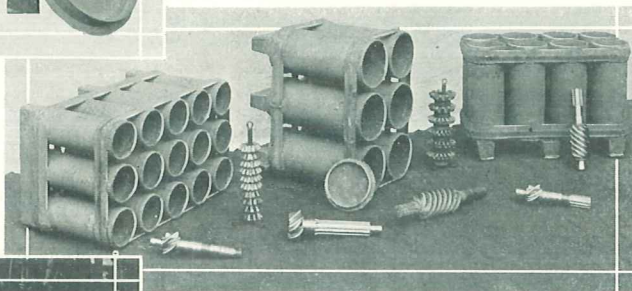
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Pump Impeller Blades for handling highly  
corrosive developing fluids in the Motion  
Picture Industry of REZISTAL 4



Carburizing Pots and Boxes of  
REZISTAL 4



Glass Annealing Furnace Hearth and  
Parts of REZISTAL 4

# CORROSION AND HEAT RESISTING STEELS

## REZISTAL 4

Non-hardenable Austenitic Chromium Nickel Steel of Group I  
Carbon .25 max., Chromium 19.00 to 21.00, Nickel 24.00 to 26.00

REZISTAL 4 is an alloy with great resistance to corrosion in the many acids and alkalis, and at the same time with high strength and resistance to scaling at elevated temperatures. It possesses easier forming properties than REZISTAL 3C or REZISTAL 7, which are also used for high temperature purposes.

This splendid resistance to scaling has made it a popular grade for annealing boxes, carburizing boxes, trays, and pans in heat treating furnaces, bottom plates, traveling chain parts, rollers, and many other parts of heat treating equipment con-

stantly exposed to high temperatures. It has also been used for parts of boiler plant equipment and stokers, and for high temperature trays and flues in connection with the roasting of ores. In the presence of  $\text{SO}_3$  gas, REZISTAL 4 is to be preferred over the other high temperature steels such as REZISTAL 3 or REZISTAL 7 or STAINLESS IRON 24. For  $\text{SO}_2$  gases, the other grades, just mentioned, will probably be superior to REZISTAL 4.

See page 17 for proper choice of heat resisting steel.

### Physical Properties, Annealed

Tensile Strength .....	90,000 to 110,000	Specific Electrical Resistance (microhms per cu. cm.)	
Yield Point .....	45,000 to 50,000	100 deg. F.	102.2
Elongation in 2" .....	30 to 40%	Coefficient of Linear Expansion (per deg. C.)	
Reduction of Area .....	35 to 45%	20 to 300 deg. C.	0.0000163
Brinell .....	160 to 190	300 to 600 deg. C.	0.0000180
Charpy .....	80	600 to 900 deg. C.	0.0000200
Specific Gravity .....	7.84	Modulus of Elasticity .....	28,000,000 to 30,000,000

### Strength at Elevated Temperatures

Strength at elevated temperatures is an important characteristic of this alloy. Short time tests

have indicated the following strengths at elevated temperatures:

Temperatures	Tensile Strength
1200° F.	63,000
1300° F.	50,000
1400° F.	40,000
1500° F.	25,000
1600° F.	16,000
1700° F.	12,000
1800° F.	10,000

### Fabrication

For complete details see pages 19 to 31.

**Forging:** Should be started at 2100°F., and should be finished at 1700°F. or above. See page 19 for further instructions.

**Upsetting:** Should be done at such a temperature as to finish at between 1700° and 1800°F.

**Annealing:** For maximum softness anneal at 2100°F. Parts fabricated from sheets or light plates may be air cooled while heavy parts should be water quenched. Final anneal to relieve fabricating strains and produce best corrosion and heat resisting properties, should be at a temperature not over 1900°F.

**Forming:** This grade can be readily formed to most desired shapes.

**Drawing and Spinning:** After annealing at 2100°F., this grade may be successfully drawn; difficulty is experienced in attempts to spin.

**Machining:** Can be commercially machined, but not as easily as the special free machining types.

**Welding:** Possesses splendid welding characteristics. See page 25 for further details.

**Riveting:** Can be riveted if desired, but its welding characteristics make welding the usual method of fabrication. When riveting is used it should be carried out at 1950°F.

**Pickling:** See page 19.

**Polishing and Buffing:** See page 23.

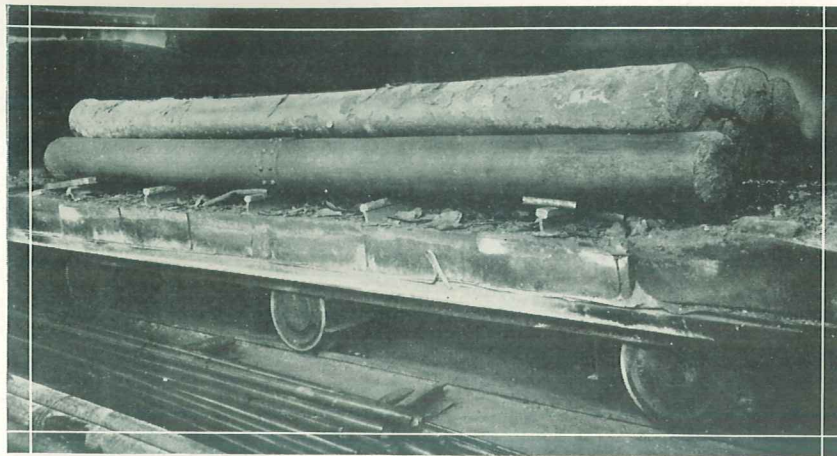
**Brazing and Soldering:** See page 27.



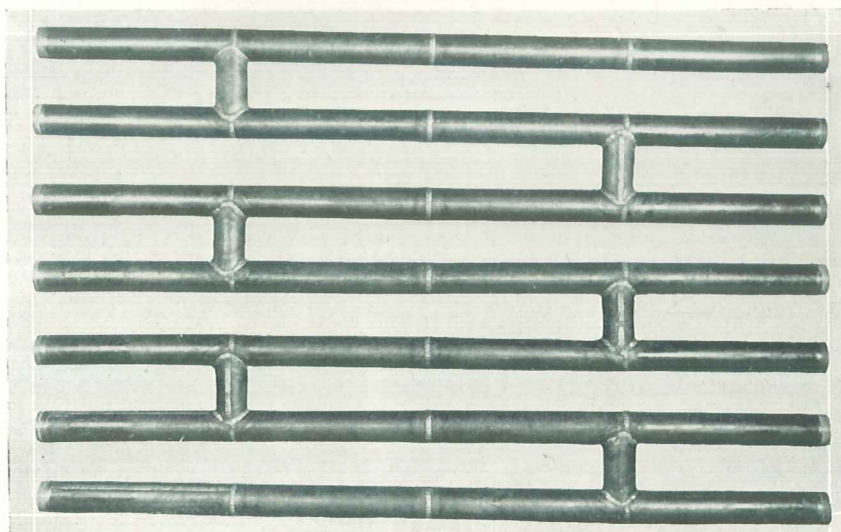
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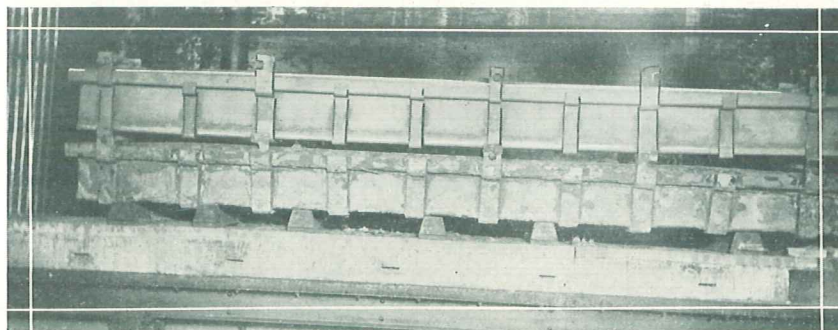
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Comparison of REZISTAL and Ordinary Steel Annealing Tubes



REZISTAL 7 Heating Tubes



Comparison of REZISTAL 7 and Ordinary Steel Annealing Boxes

## REZISTAL 7 (NCT-3)

Non-Hardenable Austenitic Chromium Nickel Steel of Group I  
Carbon .25 max., Chromium 24.00 to 26.00, Nickel 19.00 to 21.00



This grade is perhaps the best of all the heat resisting steels for all general purposes except in those cases where a high percentage of  $\text{SO}_3$  gas is present, in which case REZISTAL 4 is recommended. Its resistance to general corrosion is superior to that of REZISTAL KA2 for certain specific applications.

REZISTAL 7 has found wide use for such

applications as water and rider sheets in sheet mills, for hydrogenation tubes and equipment, heat exchangers, furnace doors, skids, retorts, and tubes in general for high temperature service. It has also been used with considerable success for annealing boxes and tubes and for carburizing boxes.

See page 17 for proper choice of heat resisting steel.

### Physical Properties, Annealed

Tensile Strength .....	100,000 to 110,000	Coefficient of Linear Expansion (per deg. C.)	
Yield Point .....	45,000 to 55,000	0 to 100 deg. C.	0.000016
Elongation in 2" .....	45 to 55%	0 to 600 deg. C.	0.000018
Reduction of Area .....	50 to 60%	0 to 1000 deg. C.	0.000020
Brinell .....	150 to 180	Modulus of Elasticity .....	28,000,000 to 30,000,000
Charpy .....	60		
Specific Gravity .....	7.72		

### Strength at Elevated Temperatures

For temperatures over 1600°F., REZISTAL 7 has higher strength than many of the heat resisting

steels. Short time tests at elevated temperatures give the following results:

Temperature	Tensile Strength
1300° F.	45,000 lb.
1475° F.	30,000 lb.
1650° F.	17,000 lb.

### Fabrication

See pages 19 to 31 for further details.

**Forging:** Should be started at 2100° F. to 2150°F., and should be finished at not under 1700°F. See page 19 for further details.

**Upsetting:** The temperature for upsetting should be such that the work is finished between 1700°F. and 1850°F.

**Annealing:** For maximum softness anneal at 2100°F., followed by an air cool for sheet and light plates. Heavier sections require a water quench from the annealing temperature. For best resistance to heat, a final anneal at 1900°F. is recommended.

**Forming:** Can be formed to most desired shapes, but presents slightly more difficulty than REZISTAL 4.

**Drawing and Spinning:** Can be drawn, but spinning should not be attempted. See page 21 for further details.

**Machining:** Can be machined, but offers slightly greater difficulty than some of the lower alloyed steels. See page 31.

**Welding:** An excellent welding material, and this is the recommended manner of fabrication.

**Riveting:** While there is no difficulty in riveting REZISTAL 7, its welding characteristics make welding the preferred method. When riveting is used, it should be carried out at 1950°F.

**Pickling:** See page 19.

**Polishing and Buffing:** See page 23.

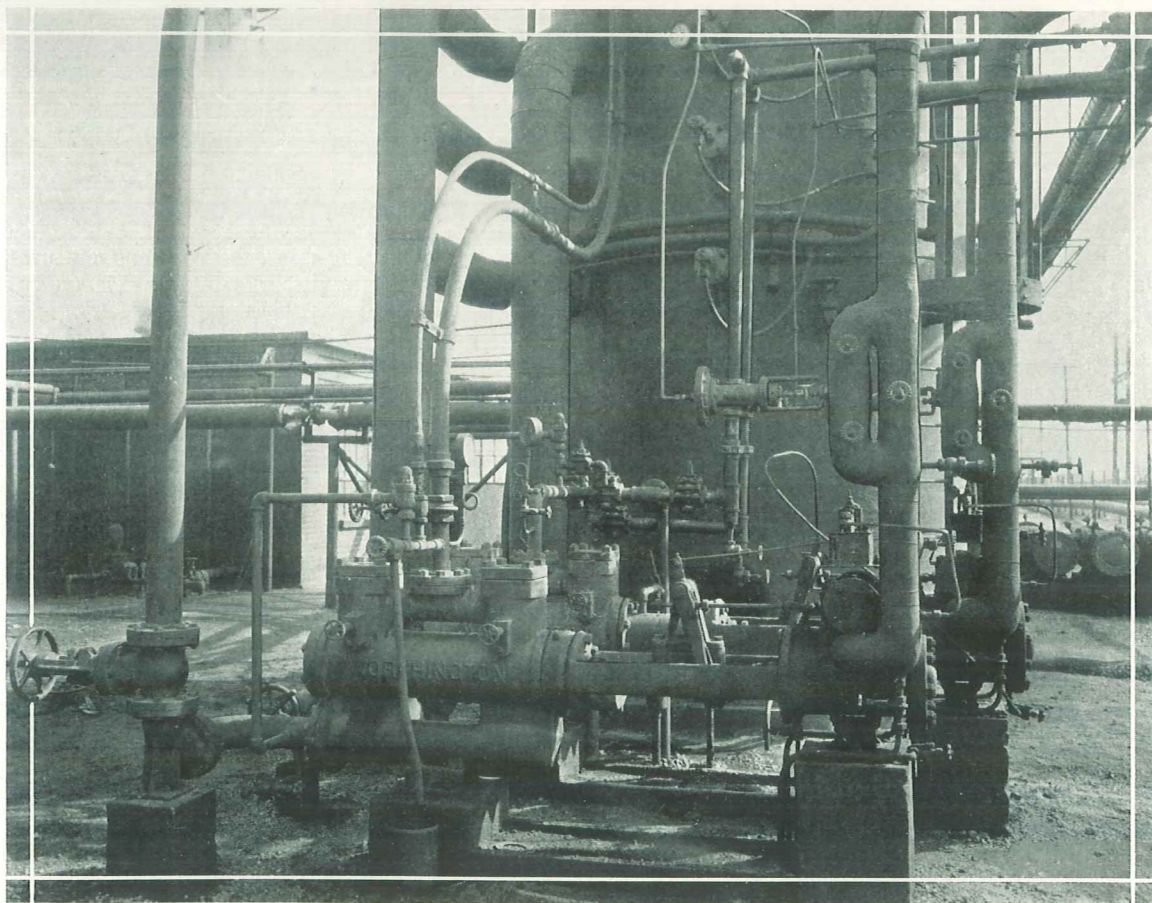
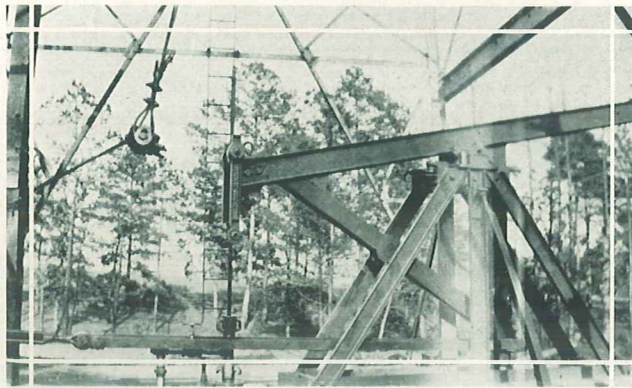
**Brazing and Soldering:** See page 27.



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# CRUCIBLE STEEL COMPANY OF AMERICA

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Pump Rods and Valve Parts of this Oil Field Equipment are made of REZISTAL 2600

## REZISTAL 2600

Non-hardenable Austenitic Chromium Nickel Steel of Group I

Carbon .25 max., Chromium 7.00 to 10.00, Nickel 21.00 to 23.00, Copper 1.00 to 1.50

REZISTAL 2600 was one of the first austenitic, corrosion resisting steels manufactured in this country. Among its early applications was that of periscope tubes, pump shafts for the oil fields and mine water, and many other applications for resistance to corrosion. A great many of its early applications have been replaced by the use of RE-

ZISTAL KA2 or some other member of the corrosion resisting steel family. However, REZISTAL 2600 remains as an excellent special purpose steel rendering good service for oil pump shafts and parts in the crude oil producing field, and for resistance to dilute sulphuric acid, soda ash, calcium chloride brine, and other special applications.

### Physical Properties, Annealed

Tensile Strength .....	85,000 to 95,000	Specific Gravity .....	7.98
Yield Point .....	45,000 to 55,000	Specific Heat .....	0.07
Elongation in 2" .....	30 to 40%	Specific Electrical Resistance (microhms per cu. cm.)	86.4
Reduction of Area .....	45 to 55%	Coefficient of Linear Expansion (per deg. C.)	
Brinell .....	160 to 190	20 to 300 deg. C.	0.0000168
Charpy .....	80	300 to 600 deg. C.	0.0000180
Thermal Conductivity (gram. calories per		600 to 900 deg. C.	0.0000200
cu. cm. per sec. per deg. C.)	0.074	Modulus of Elasticity .....	28,000,000 to 30,000,000

### Fabrication

For complete details see pages 19 to 31.

**Forging:** Should begin at 2050°F., and should finish not under 1600°F.

**Upsetting:** Should be done at such a temperature that the work is finished between 1650° and 1800°F.

**Annealing:** Should be done at 1900°F. followed by an air cooling for thin sections, and a water quench for heavier sections.

**Forming:** This steel possesses similar forming characteristics to REZISTAL KA2.

**Drawing and Spinning:** Can be successfully

deep drawn, but spinning is not recommended.

**Machining:** Can be commercially machined. See page 31.

**Welding:** Can be successfully welded. See page 25.

**Riveting:** Can be successfully riveted. The rivets should be heated to finish at a temperature of 1650° to 1800°F.

**Pickling:** See page 19.

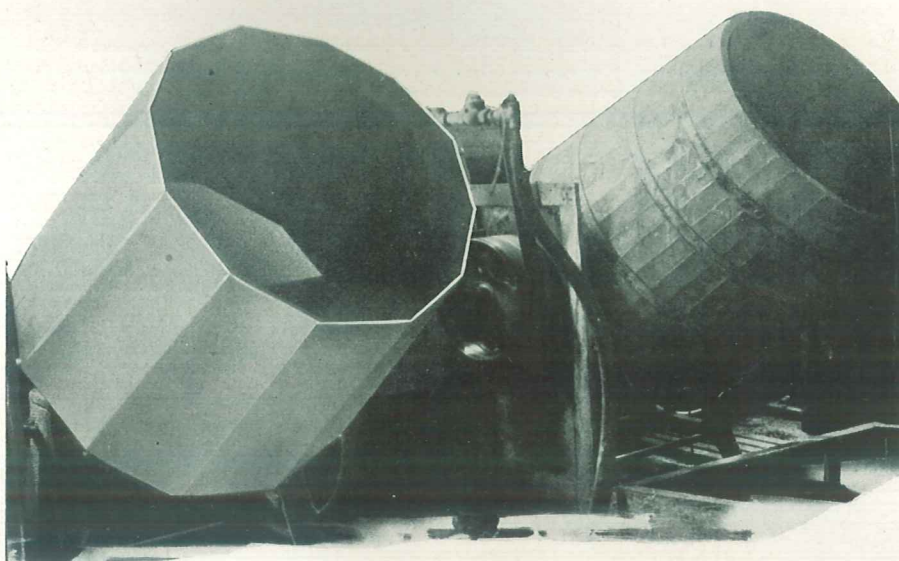
**Polishing and Buffing:** See page 23.

**Brazing and Soldering:** See page 27.



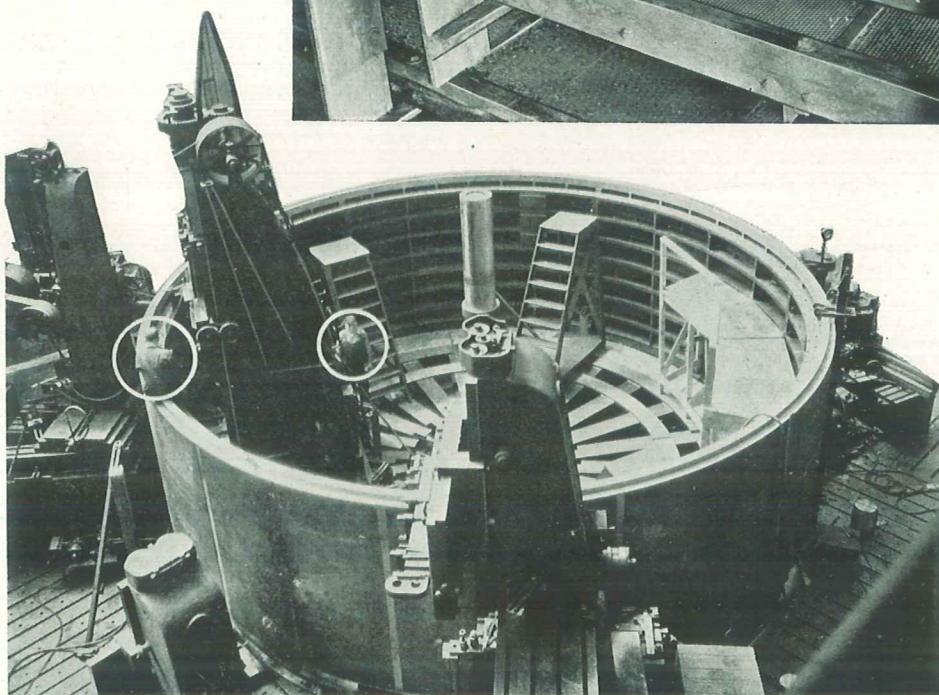
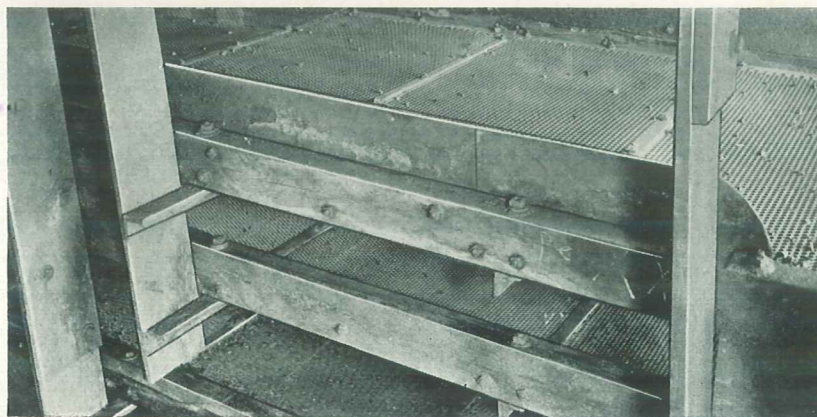


# CRUCIBLE STEEL COMPANY OF AMERICA



Rezistal Stainless Iron 12 Tumbling and Pickling Barrel outlasting many times and replacing the wooden barrel formerly used

Rezistal Stainless Iron 12 Coal Screens



Rezistal Stainless Iron 12 will be used in this Huge Gate for Boulder Dam



## REZISTAL STAINLESS IRON 12

Hardenable Chromium Steel of Group II  
Carbon .12 max., Chromium 10.00 to 13.50

REZISTAL STAINLESS IRON 12 is one of the most important corrosion resisting steels. It is resistant to the corrosive action of the atmosphere, fresh water, and a variety of the milder acids and alkalis. An important characteristic is that it is capable of being heat treated to a wide range of mechanical properties similar to the SAE alloy

steels, as indicated by the following chart. Because of its good mechanical properties readily controlled by heat treatment and its resistance to corrosion, it has found wide applications for such parts as turbine blades, meat hooks, sucker rods, pump shafts and parts, machine parts, spoons, forks, and many other applications.

### Fabrication

See pages 19 to 31 for further details.

**Forging:** Should start at 2050° to 2150°F. and can be finished as low as 1400°F.

**Upsetting:** Should be carried on so as to finish at 1450° to 1600°F.

**Annealing:** Should be annealed at 1450°F. allowing a thorough soaking at this temperature and followed by a furnace cool.

**Forming:** This grade when in the annealed condition can be easily formed into many shapes.

**Drawing and Spinning:** Can be drawn when annealed but spinning is not recommended.

**Machining:** Can be commercially machined but where extensive machining is contemplated the use of REZISTAL STAINLESS IRON FREE MACHINING 2 is recommended. See pages 59 to 61.

**Hardening and Tempering:** Can be hardened in either air or oil from 1750° to 1850°F.

When air hardening is resorted to, a temperature in the upper part of this range should be used. The tempering should be at the proper temperature to give the desired properties as indicated in the following table. The note on tempering should be carefully considered. REZISTAL STAINLESS IRON 12 possesses splendid deep hardening properties. Tests on a 7" round bar showed equal hardness at center and surface.

**Welding:** Can be successfully welded but must be annealed after welding, otherwise a hard and brittle zone will be present in the weld deposit and adjacent metal subjected to the high heat.

**Riveting:** Can be successfully riveted. The rivets should be heated to finish between 1450° and 1500°F.

**Pickling:** See page 19.

**Polishing and Buffing:** See page 23.

**Brazing and Soldering:** See page 27.

### Mechanical Properties, Room Temperature Quenched in Oil From 1800° F.

Tempered At	Prop. Limit	Yield Point	Tensile Strength	Elongation in 2"	Reduction of Area	Charpy Ft. Lbs.	Brinell
400° F.	78,000	179,000	182,000	18.0%	62.8%	57.0	363
500° F.	85,000	176,000	179,000	17.1%	62.3%	60.6	363
600° F.	106,000	173,000	179,000	16.6%	61.4%	58.8	363
700° F.	105,000	174,000	179,000	17.8%	63.3%	57.9	363
800° F.	110,000	176,000	180,000	17.7%	62.6%	43.6	363
900° F.	112,000	162,000	181,000	19.8%	63.1%	15.4	363
1000° F.	66,000	168,000	175,000	17.2%	65.4%	6.0	363
1050° F.	.....	112,000	135,000	21.2%	71.3%	...	269
1100° F.	66,000	105,000	119,000	21.8%	69.9%	40.7	241
1200° F.	54,000	86,000	106,000	23.9%	71.7%	128.3	228
1300° F.	48,000	82,000	97,000	26.6%	70.9%	144.0	187
1400° F.	44,000	70,000	90,000	28.4%	73.5%	144.3	183
Annealed 1450° F.	45,000	60,000	87,000	31.2%	73.9%	...	170

**Note on Tempering:** It is desirable to avoid tempering between 800° and 1100°F. as there is quite a drop in Charpy impact values within this range, coincidental with which there is a drop also in resistance to corrosion. This condition disappears

when the steel is tempered at 1100°F. or over.

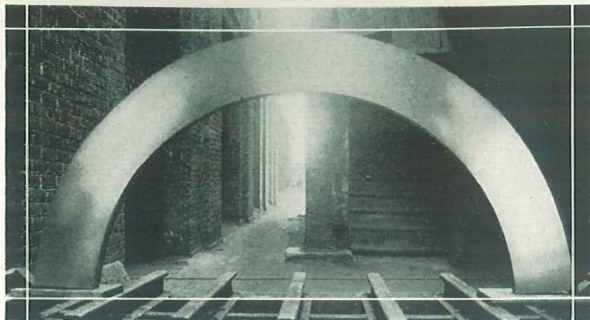
It is, therefore, strongly urged that this steel never be ordered to a hardness range of 240 to 300 Brinell if the full properties of the material are desired.



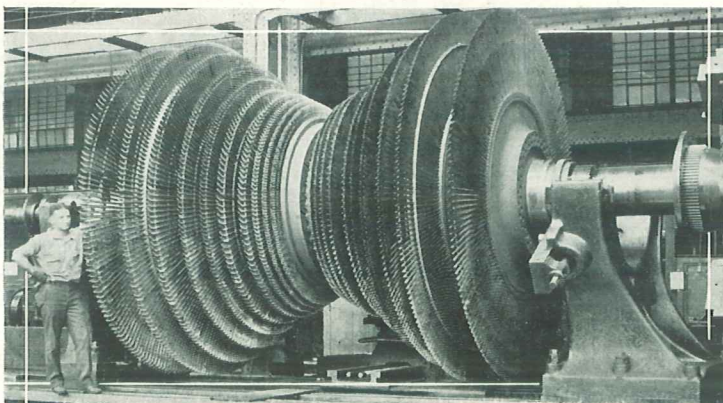
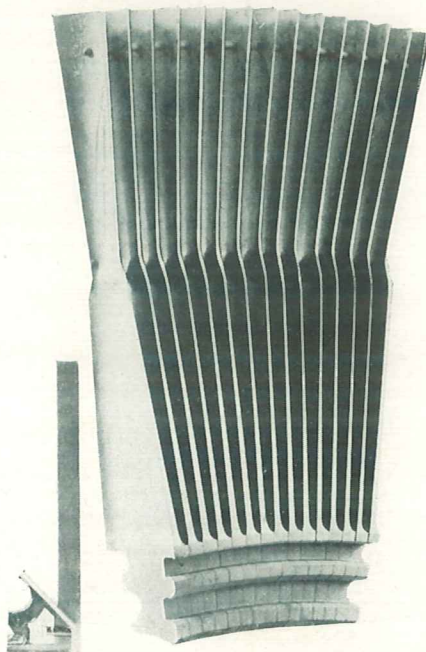
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CRUCIBLE STEEL COMPANY OF AMERICA

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Nozzle Block REZISTAL STAINLESS IRON 12



REZISTAL STAINLESS IRON 12 Turbine Blading  
Individual Blades and Assembled Turbine



# CORROSION AND HEAT RESISTING STEELS

## Special Turbine Blading Quality

When REZISTAL STAINLESS IRON 12 is used for turbine blading, it is necessary to produce in the steel special properties that are not required, or generally desired, for other applications of this steel. It is therefore necessary to melt this material with special care and process it in a special manner to bring out the particular properties which are necessary for this application. It is not only necessary to develop the desired properties for service conditions but also to develop the special characteristics required for the manufacturing and fabricating problems of making turbines. The chemical analysis is held to a closer range than normal. The internal structure of this grade is the finest obtainable as far as uniformity of grain and cleanliness are concerned. The steel must be so made as to allow many successive operations of forging and pickling without any deleterious effect on the surface. This is of advantage when it is realized that many of these parts are not machined after forging but are put into service

in the pickled condition.

The response to heat treatment of this grade is similar to REZISTAL STAINLESS IRON 12 and a similar range of mechanical properties may be obtained by variations of the tempering temperature. However, turbine blades are usually heat treated by quenching in oil from 1750°F. and tempering at 1200°F., which produces the following mechanical properties:

Tensile Strength .....	100,000
Yield Point .....	80,000
Elongation in 2" .....	20%
Reduction of Area .....	60%
Izod, ft. lb. ....	50

Aside from its use for turbine blading, this steel is used for applications where the highest quality of REZISTAL STAINLESS IRON 12 is desired. This grade is practically a custom made steel and is, therefore, naturally more costly than the regular REZISTAL STAINLESS IRON 12.

## Physical Properties, Annealed

Thermal Conductivity (gram-calories per cu. cm. per sec. per deg. C.)	.096
Specific Gravity .....	7.75
Specific Heat .....	.159
Specific Electrical Resistance (microhms per cu. cm.)	
At room temperature	60
700 deg. C.	113

Coefficient of Linear Expansion (per deg. C.)—	
0 to 100 deg. C.	.0000106
0 to 300 deg. C.	.0000109
0 to 600 deg. C.	.000012

Modulus of Elasticity.....28,000,000 to 30,000,000

## In Cutlery Manufacture

While the higher carbon Stainless Steels such as REZISTAL STAINLESS STEELS A, B, B100, or BM are most suitable for use in stainless cutlery, the recent demand for a cheaper stainless cutlery steel has led to the adoption of REZISTAL STAINLESS IRON 12 for this application. Although it is impossible to harden this grade by quenching and tempering to over 42 Rockwell C, our special process of hardening and cold rolling has made it possible to produce hard-

nesses up to 48 Rockwell C on strips of the size required by most cutlery makers.

For maximum hardness and greatest retention of cutting edge the use of REZISTAL STAINLESS STEELS A, B, B100, and BM is recommended in preference to REZISTAL STAINLESS IRON 12. In many applications where cost is the prime factor REZISTAL STAINLESS IRON 12, processed as outlined above, has been found satisfactory.

## For Coal Screens and Chutes

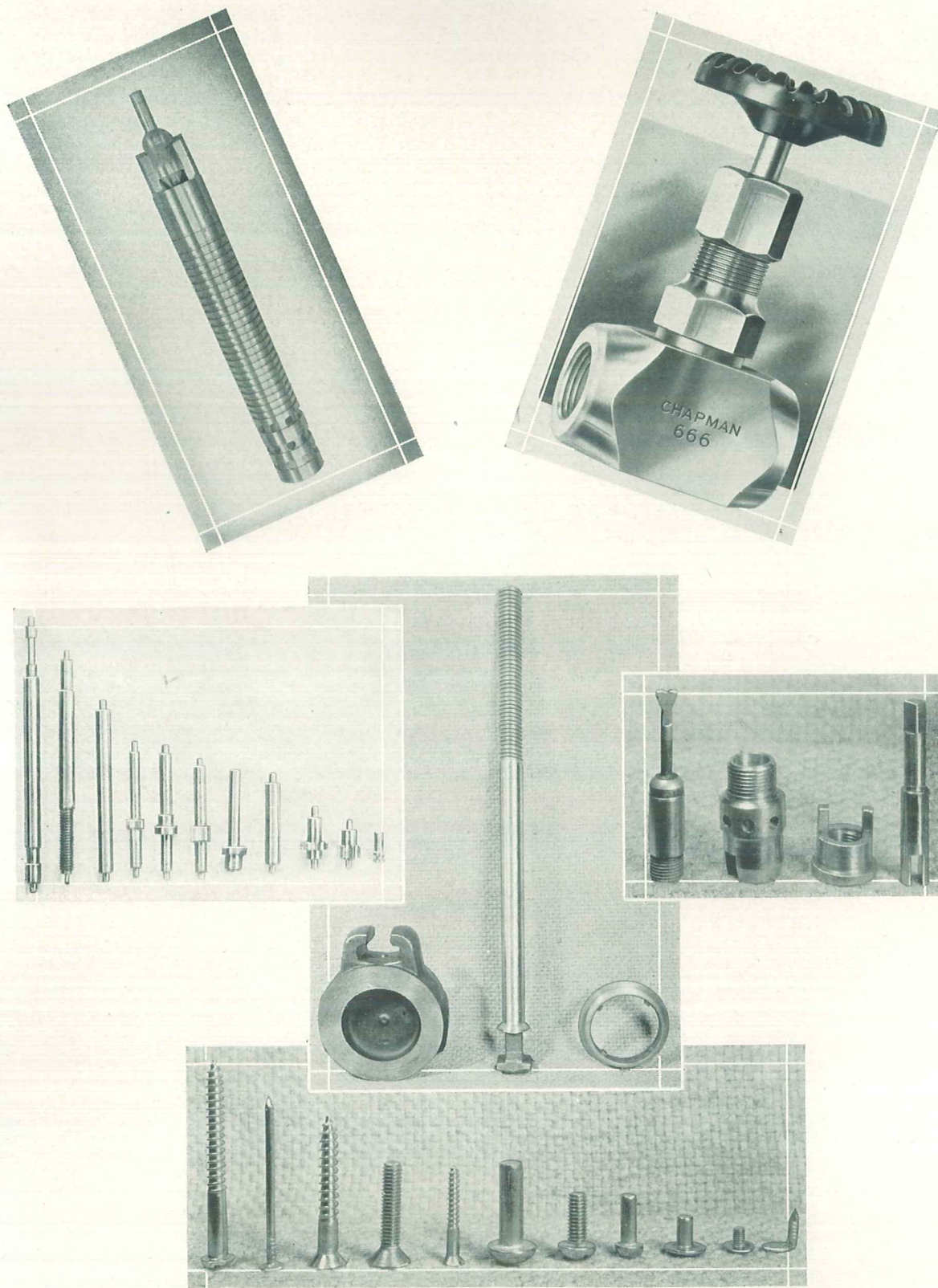
Many years of service have thoroughly demonstrated satisfaction and economy in the use of REZISTAL STAINLESS IRON 12 for coal shaker screens and for coal chutes both by the mining companies and by various coal retailers.

REZISTAL STAINLESS IRON 12 is furnished within narrow hardness limits for coal screen applications to insure good perforating quali-

ties as well as good resistance to abrasion and corrosion. A very desirable feature of the perforating qualities of this steel is that when the hole is punched there is a slight tearing of the under side of the plate which gives a hole with an under diameter larger than the upper diameter. This characteristic allows accurate sizing of the coal without any tendency to clog in the holes.



# CRUCIBLE STEEL COMPANY OF AMERICA



Typical Parts Difficult to Machine made of REZISTAL STAINLESS IRON FREE MACHINING 2 and REZISTAL FM 188



## REZISTAL STAINLESS IRON FREE MACHINING 2

Hardenable Chromium Steel of Group II

Carbon .12 max., Chromium 12.00 to 14.00, Sulphur .45 max., Molybdenum .50 max.

REZISTAL STAINLESS IRON FREE MACHINING 2 generally can be used for the same applications as REZISTAL STAINLESS IRON 12 where better machining properties are desired. It is resistant to the atmosphere and fresh water as well as a wide variety of the milder acids and alkalis. This grade will respond nicely to heat treatment as indicated in the following chart, although the maximum strength and hardness, ob-

tained with REZISTAL STAINLESS IRON 12, is not possible because of the slightly higher Chromium content of the free machining variety. In addition to its excellent machining properties (comparable with Bessemer screw stock) this grade also possesses splendid non-seizing properties which have added to its popularity for those threaded parts where freedom from seizing is desirable.

### Physical Properties, Annealed

Thermal Conductivity (gram-calories per cu. cm. per sec. per deg. C.)	.096
Specific Gravity	7.75
Specific Heat	.152
Specific Electrical Resistance (microhms per cu. cm.) At room temperature	.62

Coefficient of Expansion (per deg. C.)—	
0 to 100 deg. C.	.0000106
0 to 300 deg. C.	.0000109
0 to 600 deg. C.	.000012
Modulus of Elasticity	28,000,000 to 30,000,000

### Mechanical Properties, Room Temperatures, Quenched in Oil From 1800° F.

Treatment	Prop. Limit	Yield Point	Tensile Strength	Elongation in 2"	Reduction of Area	Brinell
As-Quenched-						
Tempered at:	17,500	76,000	134,000	6.5%	7.6%	278
200° F.	25,000	82,000	135,600	8.0%	8.0%	290
300° F.	23,000	83,500	139,500	10.0%	15.0%	278
400° F.	25,000	80,000	133,250	16.0%	32.7%	272
500° F.	28,500	83,500	134,500	15.5%	32.0%	270
600° F.	60,000	82,500	133,000	18.0%	42.5%	273
700° F.	67,500	83,000	142,750	17.0%	42.5%	295
800° F.	70,000	80,000	141,000	17.5%	42.5%	290
900° F.	63,500	75,000	139,000	18.5%	43.2%	283
950° F.	35,000	73,000	126,500	18.5%	44.0%	267
1000° F.	31,500	75,000	121,500	18.5%	46.0%	258
1050° F.	40,000	73,500	114,000	17.5%	50.5%	246
1100° F.	43,500	66,500	98,500	22.5%	54.9%	215
1150° F.	45,000	60,000	93,000	23.5%	57.0%	204
1200° F.	42,500	57,500	91,500	25.5%	58.4%	192
1250° F.	45,000	56,500	92,500	25.0%	59.0%	193
1300° F.	40,000	53,500	87,500	26.5%	59.4%	187
1400° F.	42,500	48,500	86,500	27.5%	60.2%	180
Annealed:						
1425° F.	36,500	51,500	85,250	28.5%	60.0%	184

**Note on Tempering:** It is desirable to avoid tempering between 800° to 1100°F. as there is a marked drop in Charpy impact values when tempered within this range. We have found that coincidental with this drop in impact values there

is a lowering in resistance to corrosion. This condition of reduced resistance to impact and corrosion disappears when the steel is tempered at 1100°F. or over. A hardness of 230 to 275 Brinell should never be specified.

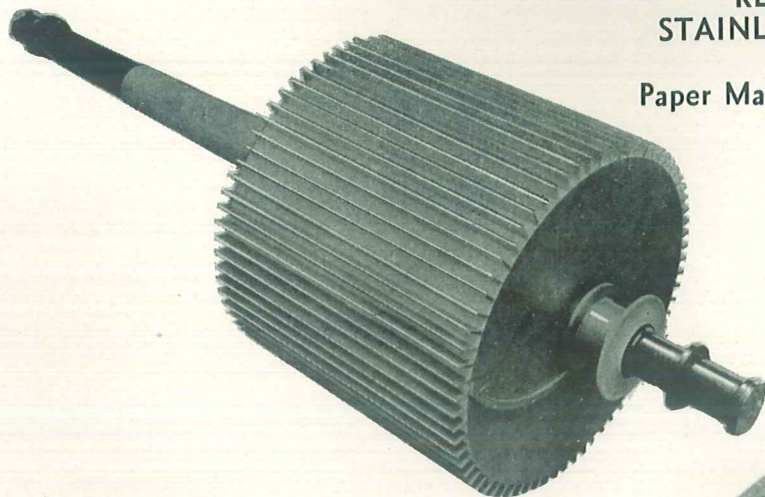


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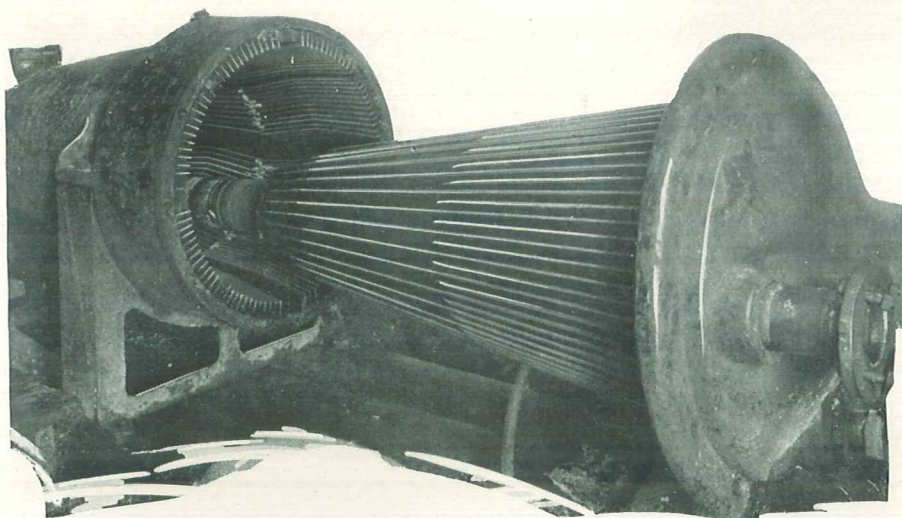
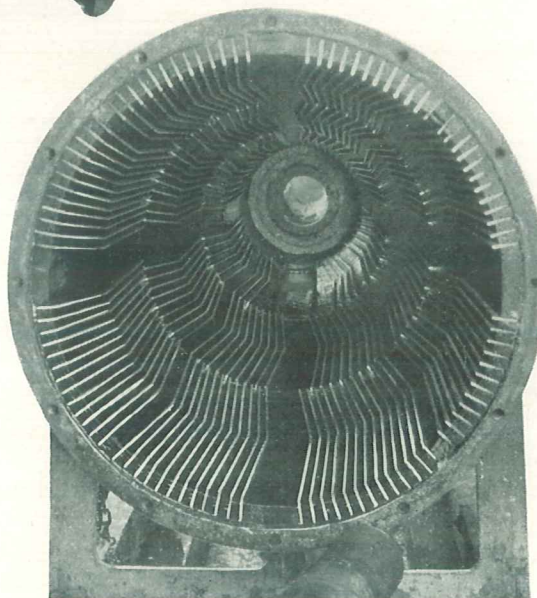
# CRUCIBLE STEEL COMPANY OF AMERICA

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## REZISTAL STAINLESS IRON 12 in Paper Making Machinery



The requirements in the paper making industry, as in most industries, have advanced materially within the past decade. Better cutting material for beater and jordan bars is needed and in certain applications it is very necessary that the pulp be extremely low in copper and iron contents. We have developed and furnished large quantities of a special type of Stainless Iron No. 12, heat treated to permit of machining or punching, which answers all of the new requirements of this industry. It is superior to the old standard carbon steel bars in that it does not increase the iron content of the pulp and obviously it is an improvement over the bronze bars because it cannot contribute any copper to the pulp. In the manufacture of fine writing and bond linen papers and for pulp used in the rayon industry, it has met with very great success. The mate-



rial is furnished in flats or special hot rolled shapes as required for beaters and jordan bars, heat treated before delivery so that the material machines readily, or may be punched, but machining is preferred in all cases rather than punching



## CORROSION AND HEAT RESISTING STEELS

### Fabrication

See pages 19 to 31 for further details.

**Forging:** Forging of STAINLESS IRON FREE MACHINING 2 should start at 2050° to 2150°F., and can be finished as low as 1400°F.

**Upsetting:** The upsetting of REZISTAL STAINLESS IRON FREE MACHINING 2 should be carried out at a very high temperature, otherwise longitudinal splitting may result. It is suggested that upsetting start at 2250°F. The upsetting should be followed by a suitable anneal or heat treatment.

**Annealing:** REZISTAL STAINLESS IRON FREE MACHINING 2 should be annealed at 1450°F., allowing a thorough soaking at this temperature and followed by a furnace cool.

**Forming:** This grade, when in the annealed condition, can be easily formed into many desired shapes.

**Drawing and Spinning:** This grade can be

successfully drawn when in the annealed condition, but spinning is not recommended.

**Machining:** This grade offers the easiest machinability of any of the corrosion and heat resisting steels. Its machining properties are similar to those of Bessemer Screw Stock.

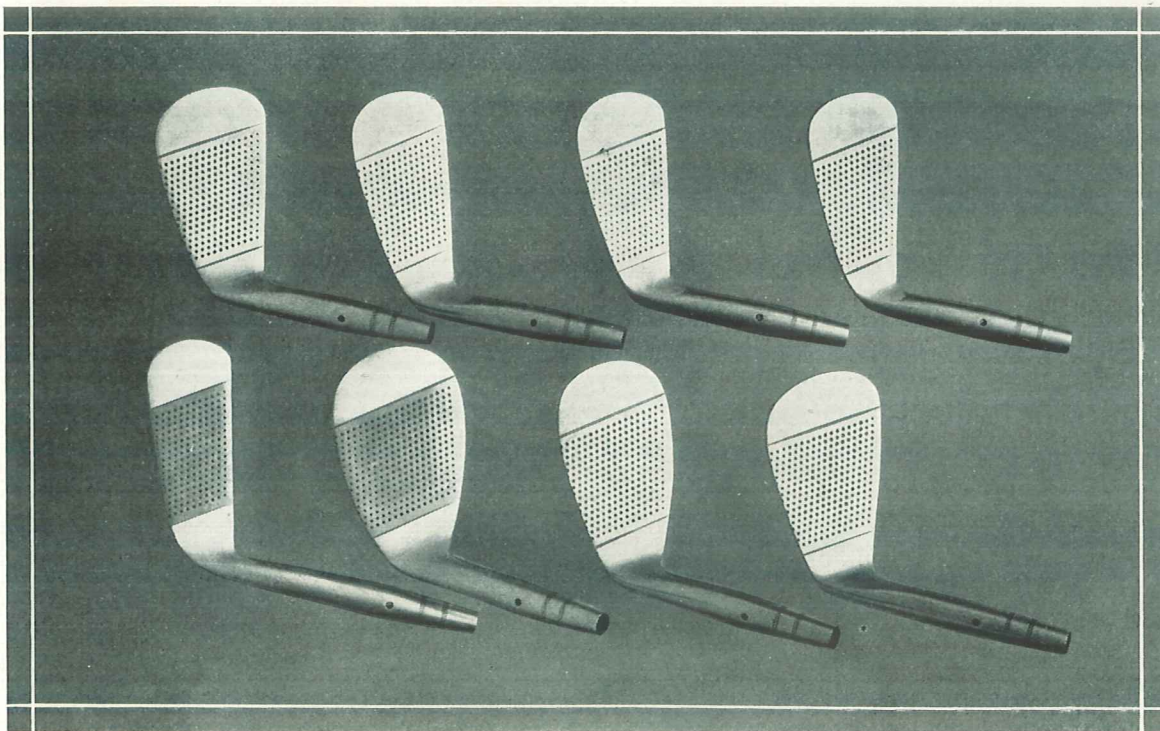
**Welding:** This grade can be successfully welded, but must be annealed after welding; otherwise a hard and brittle zone will be present in the weld deposit and adjacent metal subjected to the high heat.

**Riveting:** Riveting of REZISTAL STAINLESS IRON FREE MACHINING 2 should be carried out at a high temperature, otherwise longitudinal splitting may result. In riveting finish at about 2250°F.

**Pickling:** See page 19.

**Polishing and Buffing:** See page 23.

**Brazing and Soldering:** See page 27.



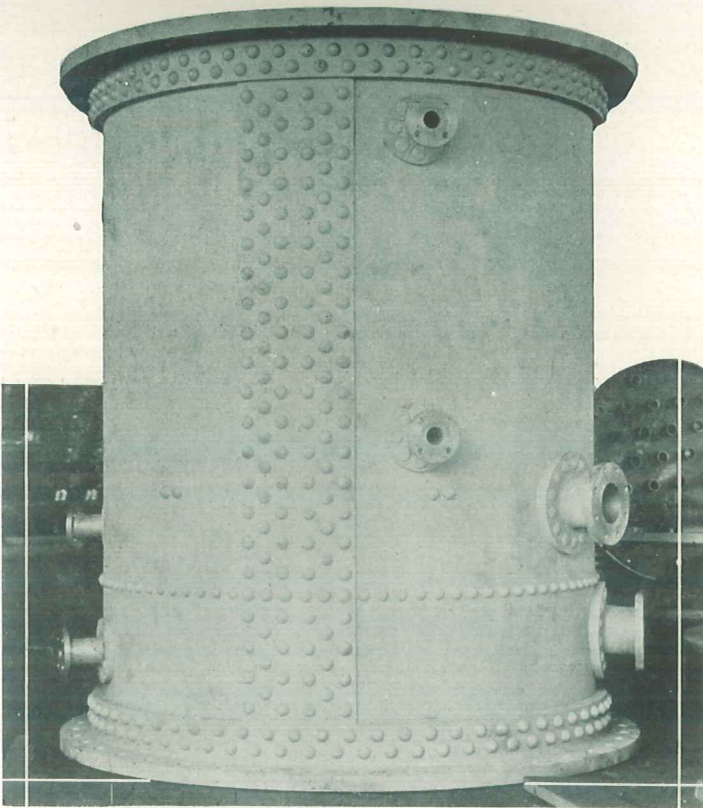
Golf Club Heads of Rezistal Stainless Iron FM2



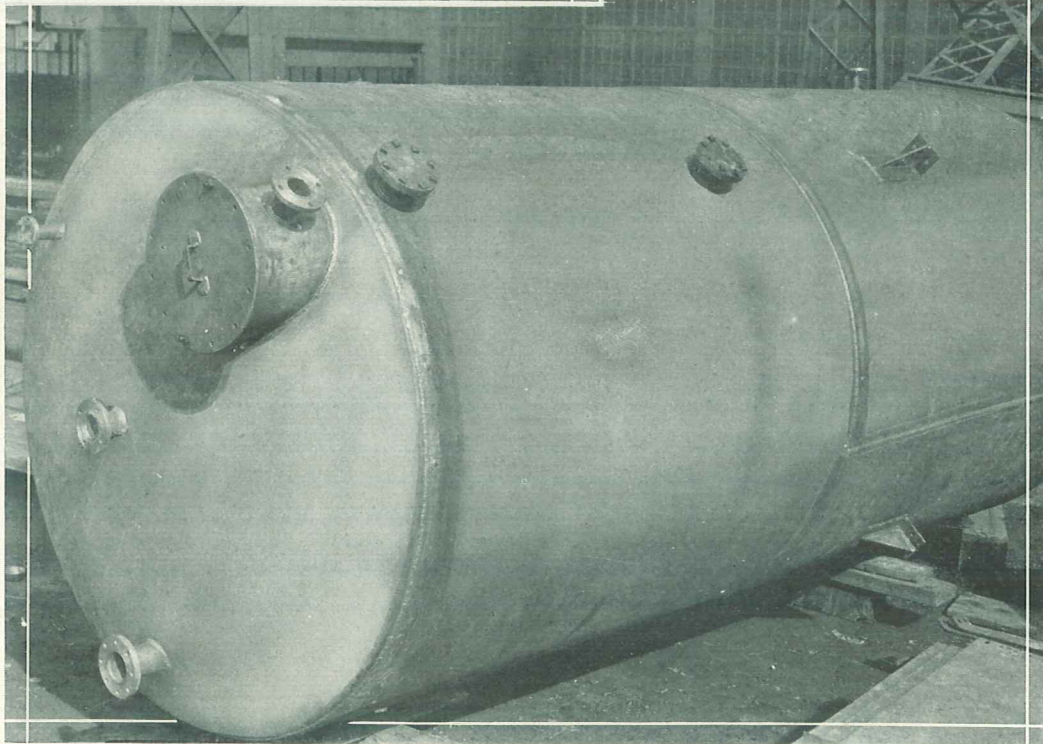
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CRUCIBLE STEEL COMPANY OF AMERICA

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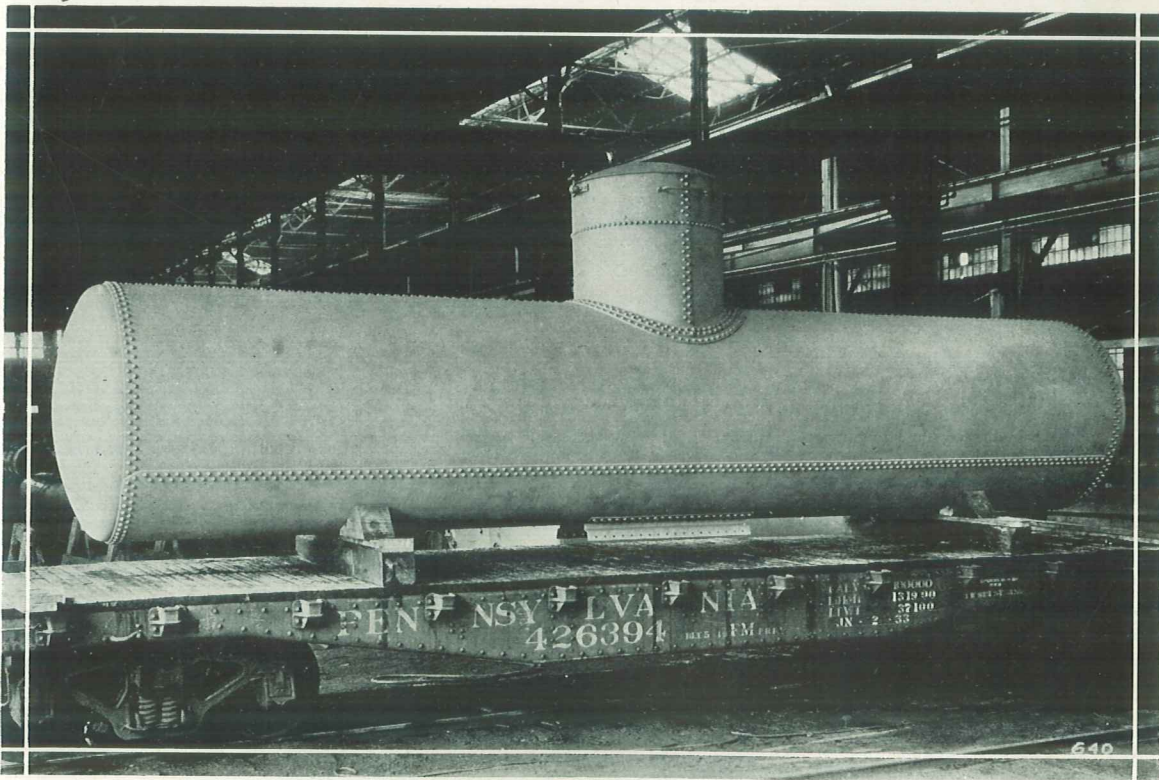
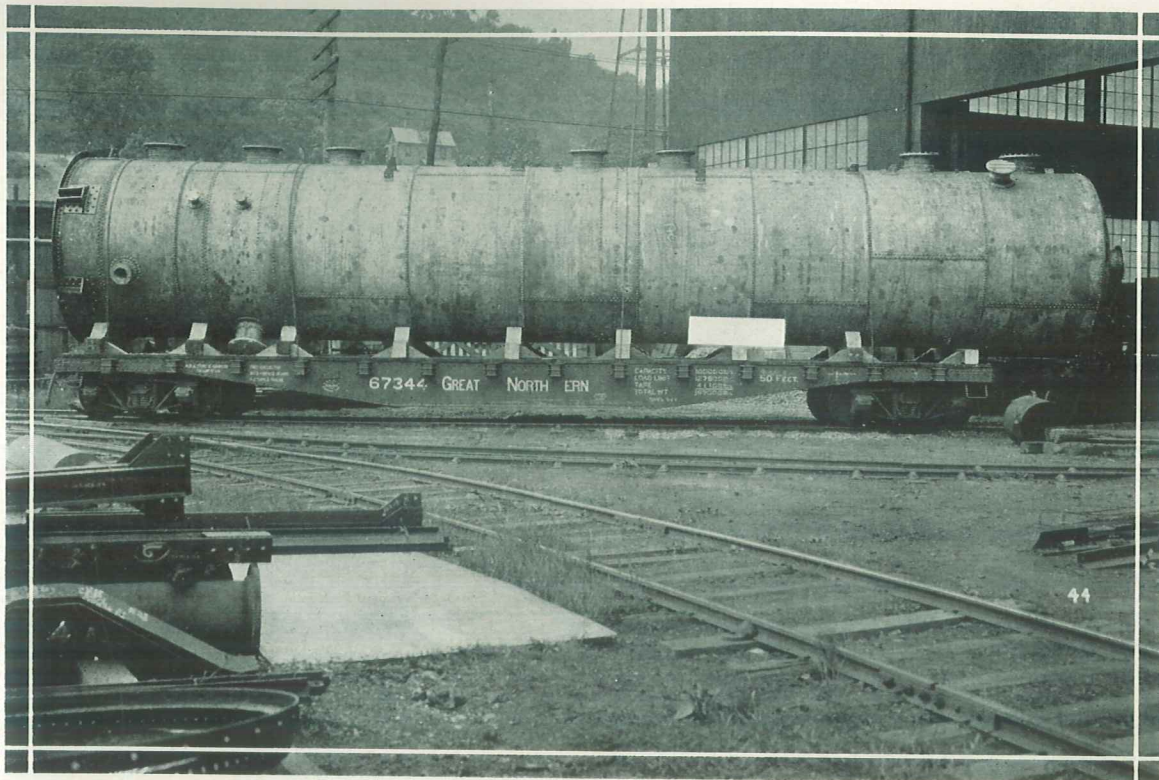
Section of Ammonia Oxidation  
Tower of REZISTAL



REZISTAL STAINLESS IRON 20 Nitric Acid Tank



# CORROSION AND HEAT RESISTING STEELS

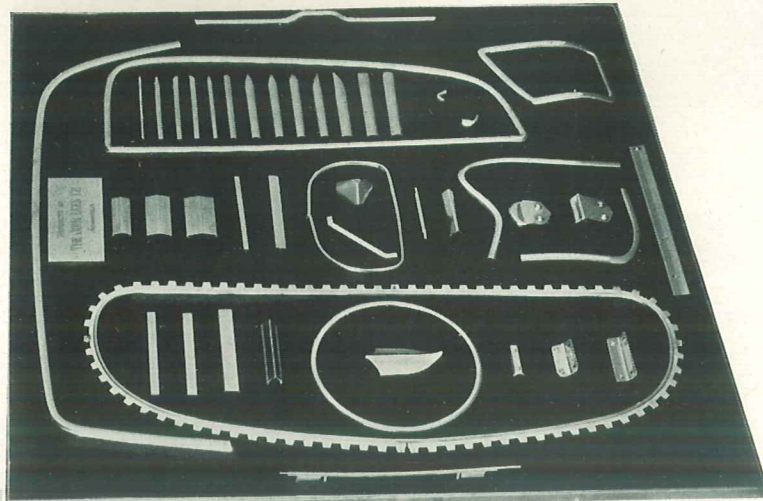


Above:—Ammonia Oxidization Tower of REZISTAL  
Below:—REZISTAL STAINLESS IRON 20 Nitric Acid Tank for Tank Car

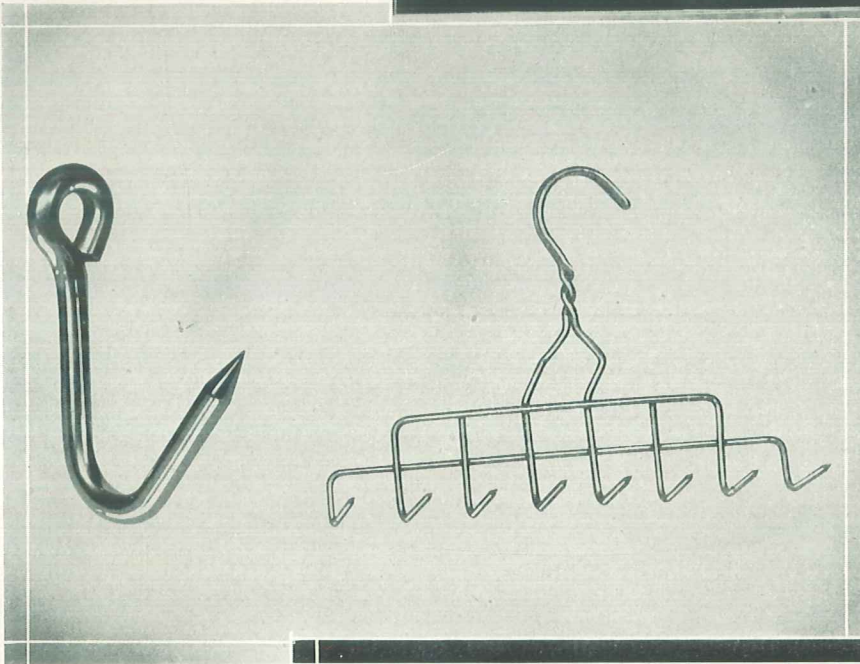


# CRUCIBLE STEEL COMPANY OF AMERICA

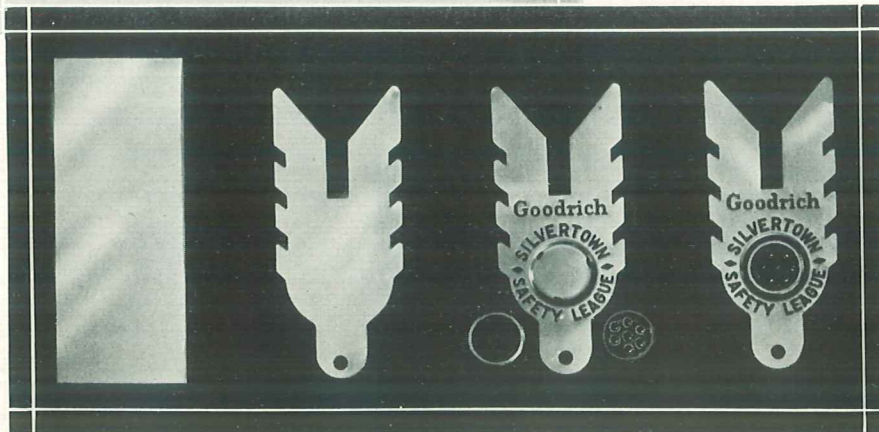
Automobile  
Trim



Meat Hook  
and  
Bacon Rack



The Evolution  
of a  
Medallion



REZISTAL STAINLESS IRON 17



# CORROSION AND HEAT RESISTING STEELS

## REZISTAL STAINLESS IRONS 17 and 20

Non-hardenable Chromium Steels of Group III

REZISTAL STAINLESS IRON 17: Carbon .12 max., Chromium 14.00 to 18.00

REZISTAL STAINLESS IRON 20: Carbon .12 max., Chromium 18.00 to 23.00

These two steels are given under the same heading because they possess similar physical and fabricating properties. The only difference is that No. 20 possesses greater resistance to scaling and to corrosion than No. 17 because of its higher chromium content. No. 17 is generally used for non-scaling purposes up to 1650°F., whereas No. 20 is used for temperatures up to 1800°F.

The resistance to corrosion of these steels, in general, is superior to that of the hardenable chromium steels of Group II, but not quite so good as that of the non-hardenable Austenitic steels of

Group I. An important exception to this is their resistance to Nitric Acid for which they have wide application in many parts of Nitrogen fixation plants, storage tanks and tank cars.

Improvements in processing now allow the welding of these grades without the excessive brittleness often experienced in the early years of the development. They possess good strength, but not the high strength of the Group II alloys or the ductility or toughness of the Group I alloys and are used where resistance to impact is not important.

### Physical Properties, Annealed

		No. 17	No. 20
Tensile Strength	75,000 to 85,000	7.72	7.70
Yield Point	45,000 to 55,000	.151	.151
Elongation in 2"	30 to 40%	Electrical Resistance (microhms per cu. cm.)	
Reduction of Area	50 to 60%	At room temperature	
Brinell	150 to 190	65	
Thermal Conductivity (gram-calories per		Coefficient of Expansion (per deg. C.)	
cm. cu. per sec. per deg. C.)	.072	0 to 100 deg. C. .0000104	
		0 to 600 deg. C. .0000117	
		Modulus of Elasticity	
		28,000,000 to 30,000,000	

### Fabrication

For complete details see pages 19 to 31.

**Forging (multiple blow operations):** For those forging operations where successive reductions and reheatings are necessary, it is recommended that forging start at 1900° to 2050°F. If reheatings are necessary, it is suggested that the last one be not over 1900°F. Each forging can be reheated as many times as desired, but should be worked all over after each reheating. In general the forging work should finish between 1300° and 1500°F.

**Upsetting (single blow operations):** This type of work should be done at temperatures not over 1400°F. The heating should be done in an indirectly fired furnace—never in an open fire.

**Annealing:** Should be annealed at 1400° to 1450°F., followed by an air cool or water quench.

**Forming:** Can be readily formed to any desired shape. Aside from REZISTAL KA2, they are the easiest to form of the corrosion and heat resisting steels. Heating to 200° to 300°F. greatly facilitates the forming of intricate shapes. Some fabricators keep the sheets in boiling water prior to forming or corrugating.

**Drawing and Spinning:** Can be drawn nearly as well as REZISTAL KA2, although slightly higher initial pressure is required. Spinning can be done, but not as easily as with REZISTAL KA2 or its special free spinning modification. Heating to 200° to 300°F. greatly facilitates the drawing of intricate shapes.

**Machining:** Can be commercially machined, although not as easily as the special free machining grades.

**Welding:** These grades may be satisfactorily welded. An anneal after welding improves ductility and corrosion resistance. If subjected to severe impact shock in service, riveting is preferred.

**Riveting:** Is the preferred method of joining these steels. The riveting should be done at a temperature not over 1400°F. The rivets should be heated in an indirectly fired furnace. All rivets should be pickled before heating and should not be heated more than once.

**Pickling:** See page 19.

**Polishing and Buffing:** See page 23.

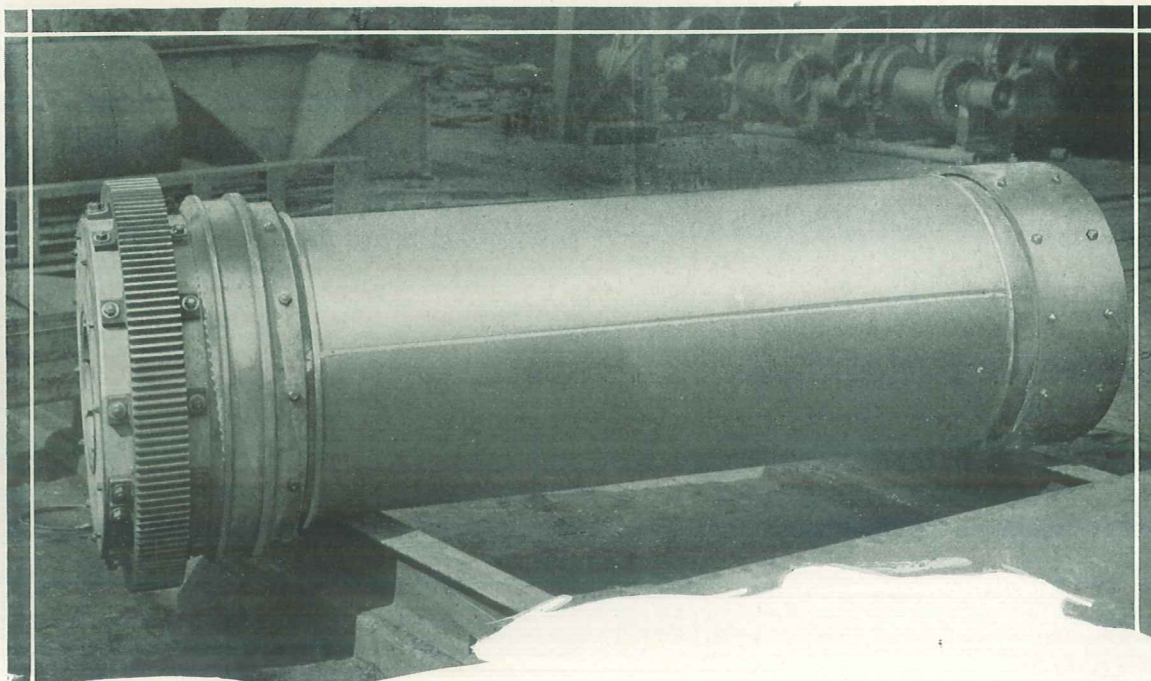
**Brazing and Soldering:** See page 27.



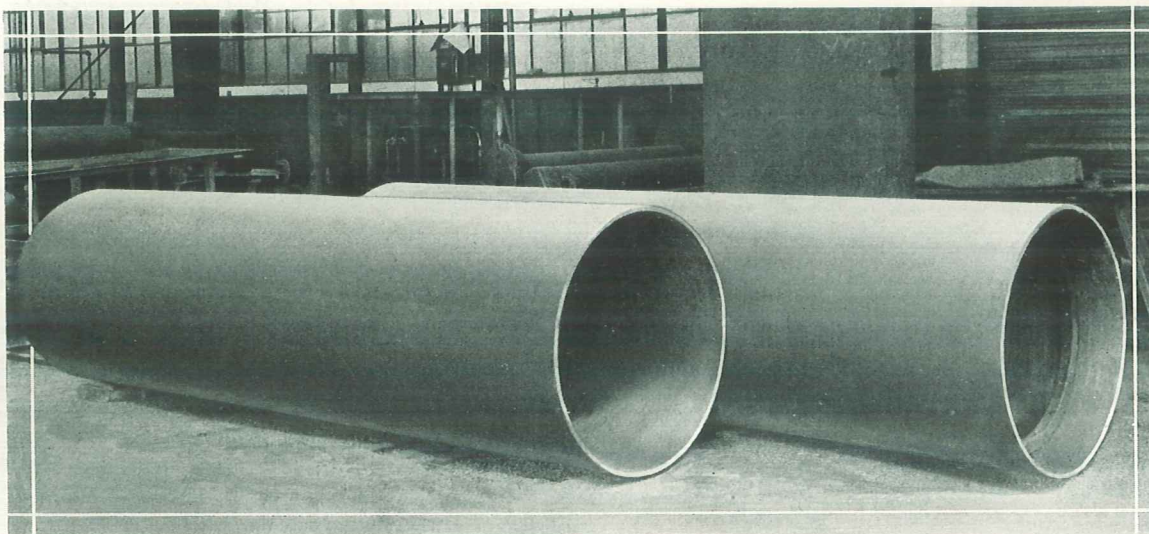
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CRUCIBLE STEEL COMPANY OF AMERICA

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Rotary Dryer of REZISTAL STAINLESS IRON 27



Rotary Retort of REZISTAL STAINLESS IRON 27



## REZISTAL STAINLESS IRON 27

Non-hardenable Chromium Steel of Group III  
Carbon .35 max., Chromium 23.00 to 30.00

This is a superior scale-resisting steel. Its resistance to scaling in many atmospheres is equal to that of REZISTAL 4 or REZISTAL 7. In high sulphur atmospheres it is superior to REZISTAL 4 or REZISTAL 7. The strength at elevated temperatures and its resistance to shock are inferior to REZISTAL 4 and REZISTAL 7. This grade is not recommended for welded construction where resistance to impact shock is an important item.

Therefore, its field is for those applications where resistance to scaling at high temperatures is required, but where resistance to impact is not important and where welding is not contemplated.

There have been successful applications of welded REZISTAL 27 for applications where no impact shock was encountered. See page 17 for proper choice of heat-resisting steel.

There are some applications where the presence of nickel is detrimental to resistance to corrosion. In many of these applications REZISTAL STAINLESS IRON 27 has been found to be the answer to the problem. It has been used with success for resistance to sodium hypochlorite solutions, red fuming nitric acid, and for tank cars for concentrated sulphuric where any iron in the acid would cause a discoloration rendering the acid unsatisfactory for the purpose intended.

### Physical Properties, Annealed

Tensile Strength .....	80,000 to 90,000	Specific Gravity .....	7.65
Yield Point .....	55,000 to 65,000	Specific Heat .....	.142
Elongation in 2" .....	20 to 30%	Electrical Resistance (microhms per cu. cm)	
Reduction of Area .....	40 to 50%	At room temperature	68
Brinell .....	160 to 200	1000 C.	118
Thermal Conductivity (gram-calories per cu. cm. per sec. per deg. C.)	.059	Modulus of Elasticity .....	28,000,000 to 30,000,000

### Fabrication

For complete details see pages 19 to 31.

**Forging (Multiple Blow Operations):** For those forging operations where successive reductions and reheatings are necessary, it is recommended that forging start at 1900° to 2050°F. In no case should the temperature be above 2100°F., as excessive grain growth, with accompanying brittleness, will be encountered when higher heats are used. The finishing temperature should be as low as possible, preferably 1300° to 1500°F. If reheatings are necessary, it is suggested that the last one be not over 1900°F. Each forging can be reheated as many times as desired, but should be worked all over after each reheating. The initial forging heat should be such that the forging will finish in the 1300° to 1500°F. range.

**Upsetting or Other Single Blow Operations:** This type of work should be done at temperatures not over 1450°F. The heating should be done in an indirectly fired furnace—never in an open fire.

**Annealing:** This grade should be annealed at 1400° to 1450°F., followed by an air cool or water quench.

**Forming:** This steel, when properly annealed, can be readily formed to any desired shape.

**Drawing and Spinning:** This grade can be drawn nearly as well as REZISTAL STAINLESS IRON 17, although more initial pressure is required. Spinning is not usually attempted on this steel.

**Machining:** Can be commercially machined, although not as easily as the special free machining grades.

**Welding:** This grade may be satisfactorily welded. An anneal after welding improves ductility and corrosion resistance. If subjected to severe impact shock in service, riveting is preferred.

**Riveting:** Is the preferred method of joining these steels. The riveting should be done at a temperature not over 1450°F. The heating of the rivets should be done in an indirectly fired furnace; and all rivets should be pickled before heating, and should not be heated for driving more than once.

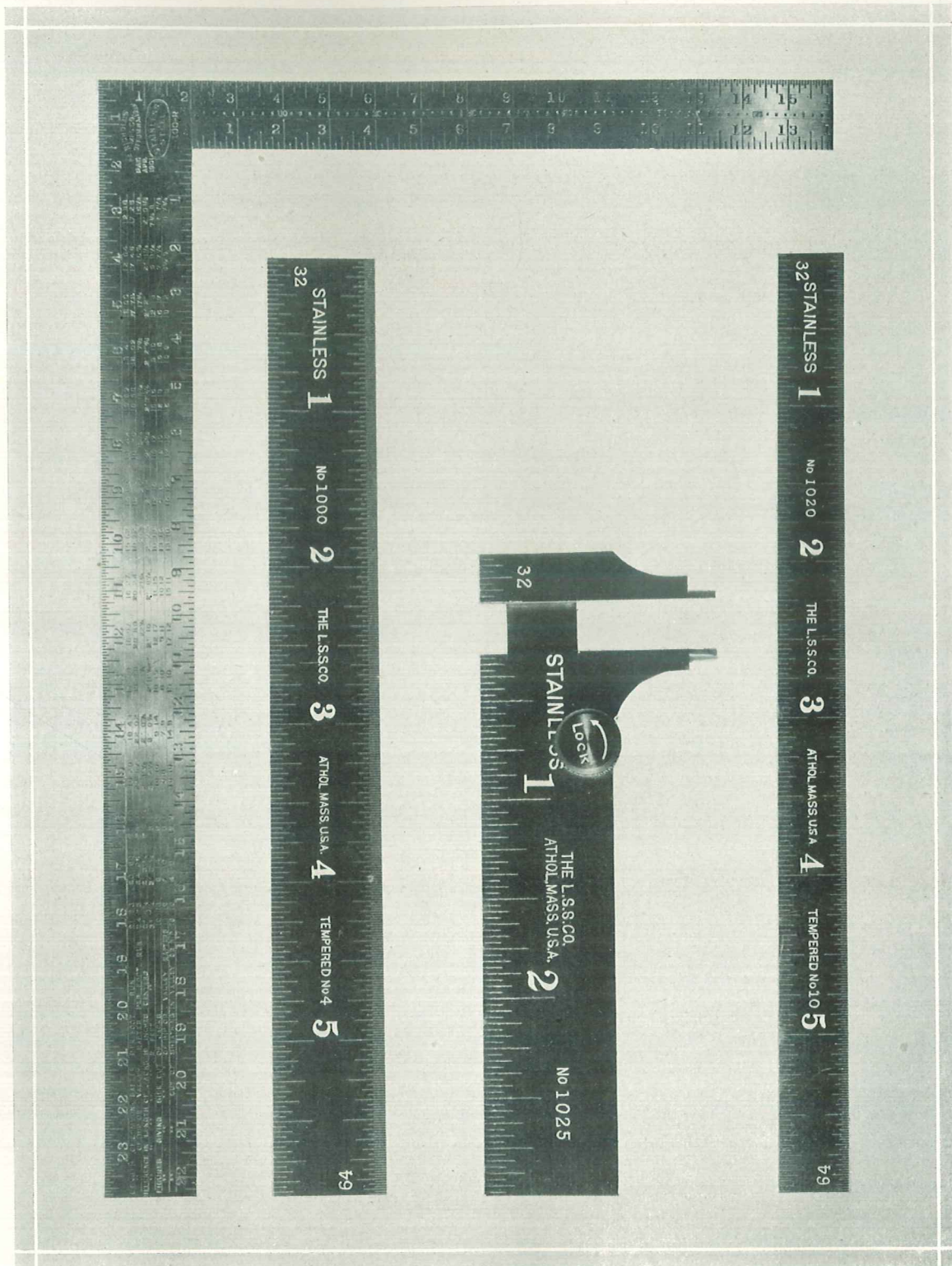
**Pickling:** See page 19.

**Polishing and Buffing:** See page 23.

**Brazing and Soldering:** See page 27.



# CRUCIBLE STEEL COMPANY OF AMERICA



REZISTAL Rules, Caliper and Carpenter's Square



## REZISTAL CUTLERY STEELS

The first corrosion-resisting steels to be offered to the trade were of the higher carbon chromium type and used mainly for cutlery purposes. It is necessary to heat treat and polish them to develop their full resistance to corrosion. They are capable of being hardened to 52 to 60 Rockwell C hardness.

This high hardness combined with corrosion resistance has lead to their use for application other than cutlery, such as ball bearings, valve trim, bushings and other parts where resistance to wear

is desired. Generally speaking, increasing carbon and to some extent increasing chromium content affords slightly higher hardness after heat treatment. The cutlery type steels resemble tool steels in that they require great care in fabrication and hardening.

Care should be taken in grinding and polishing the cutlery grades so that excessive heat is not produced by this operation, otherwise the resistance to staining will be lowered.

## REZISTAL STAINLESS STEEL GRADE A

Hardenable Chromium Steel of Group II  
Carbon .30 to .40, Chromium 12.00 to 15.00

**REZISTAL STAINLESS STEEL GRADE A** normally contains about .35 carbon and is lower in carbon and chromium content than the other Stainless Steels of the cutlery group. It is the original STAINLESS CUTLERY STEEL, and the other members of the cutlery group have been added for the purpose of obtaining a slightly greater hard-

ness and retention of the cutting edge. REZISTAL STAINLESS STEEL GRADE A is capable of heat treatment to high physical properties and shows good resistance to atmospheric and fresh water corrosion and also to corrosion by fruit and vegetable juices.

### Fabrication

**Forging:** This grade should be soaked at forging temperature about twice as long as straight carbon tool steel. The material should be heated to and soaked at a temperature of 1950° to 2050°F.

**Annealing:** This grade may be softened sufficiently for cutting, blanking or trimming by heating to 1450°F. for 6 hours and burying in some medium which will retard cooling, such as ground mica, lime or ashes.

To fully anneal heat to 1600°F., soak for 6 hours and cool slowly in the furnace.

Hardness after softening.....207 to 228 Brinell  
Hardness after full anneal.....156 to 179 Brinell

**Hardening:** For maximum hardness we suggest quenching in oil from 1850/1900°F. Large sections should be preheated to about 1250°F. before bringing up to hardening temperature. If the finished part is not to be ground and polished, the surface may be improved by packing in a neutral material during heating. Soaking should be two to three times as long as the same size section of carbon tool steel.

**Tempering:** The following table gives the ap-

proximate hardness values when reheated at various temperatures in deg. F.:

	Hardness	
	Brinell	Rockwell C
As quenched	603	57
Tempered at 400° F.	524	52
500° F.	505	51
600° F.	488	49
800° F.	516	52
1000° F.	457	45
1200° F.	290	27

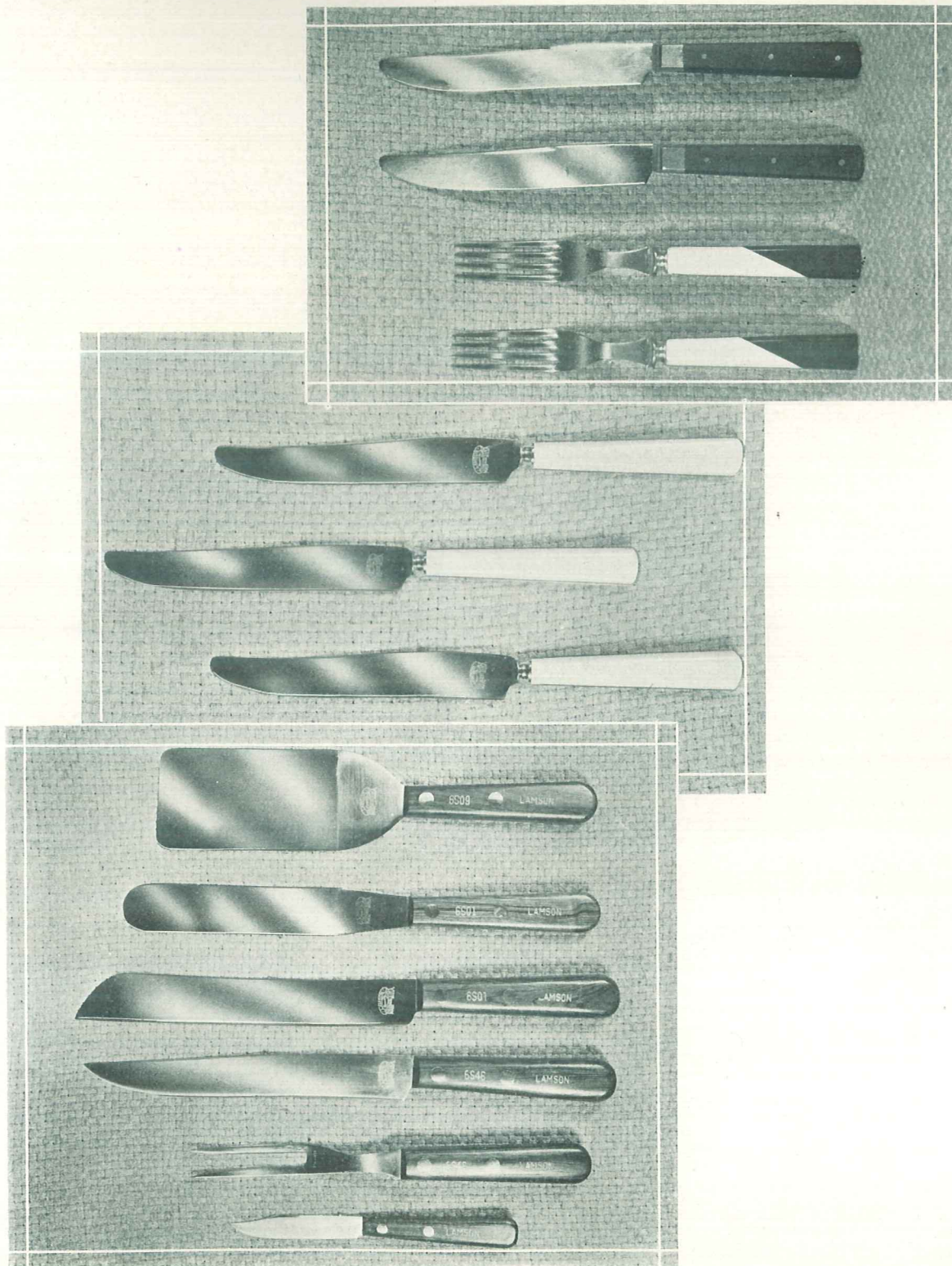
Tempering between 900 and 1100°F. tends to reduce the corrosion resistance and impact values of this grade.

### Mechanical Properties

Tempered at	Tensile Strength	Yield Point	Elongation in 2"	Reduction of Area
500° F.	250,000	220,000	4%	6%
600° F.	240,000	210,000	4%	6%
700° F.	236,000	208,000	3%	4%
800° F.	248,000	207,000	5%	17%
900° F.	250,000	204,000	9%	24%
1000° F.	254,000	193,000	8%	17%
1100° F.	200,000	170,000	10%	32%
1200° F.	160,000	131,000	12%	38%
1300° F.	146,000	120,000	15%	40%
1400° F.	132,000	103,000	16%	47%



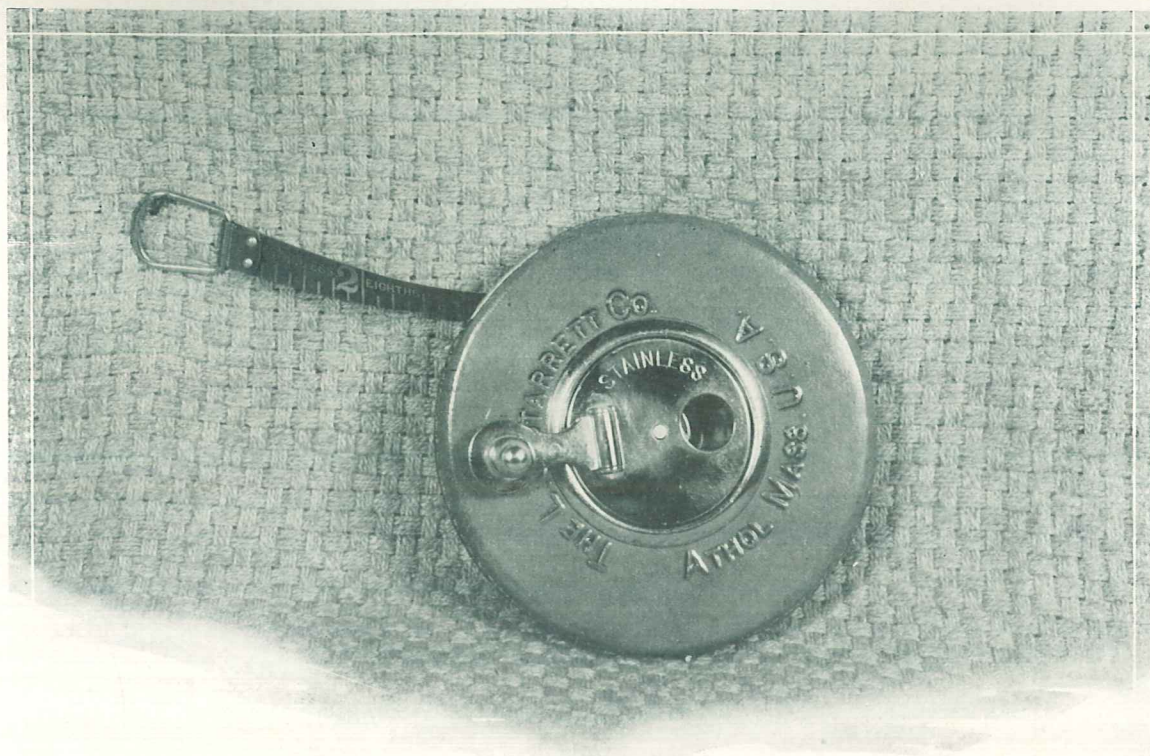
CRUCIBLE STEEL COMPANY OF AMERICA



REZISTAL STAINLESS STEELS for Cutlery



# CORROSION AND HEAT RESISTING STEELS



REZISTAL STAINLESS STEEL GRADE A. Tape

## REZISTAL STAINLESS STEEL GRADE B

Hardenable Chromium Steel of Group II  
Carbon .50 to .70, Chromium 15.00 to 18.00

**REZISTAL STAINLESS STEEL GRADE B** generally is furnished with about .60 carbon and is higher in both chromium and carbon content than REZISTAL STAINLESS STEEL GRADE A. It is used for those applications requiring greater hardness and greater retention of the cutting edge. It has a wide application for use

as surgical and dental tools, bearings, valve parts, seaming rolls and other applications where resistance to corrosion and extreme hardness is desired. Like REZISTAL STAINLESS STEEL GRADE A, this type must be heat treated and the surface should be ground and polished to develop full resistance to corrosion.

### Fabrication

**Forging:** This grade should be soaked at forging temperature about twice as long as straight carbon tool steel. The material should be heated to and soaked at a temperature of 2000-2100°F. before forging, and forging should not continue below 1750°F.

**Annealing:** This grade may be softened sufficiently for cutting, blanking or trimming by heating to 1450°F. for 6 hours and burying in some medium which will retard cooling, such as ground mica, lime or ashes.

To fully anneal, heat to 1600°F., soak for 6 hours and cool slowly in the furnace.

Hardness after softening.....217 to 241 Brinell

Hardness after full anneal.....187 to 207 Brinell

**Hardening:** For maximum hardness we suggest quenching in oil from 1850/1900°F. Large sections should be preheated to about 1250°F.

before bringing up to hardening temperature. If the finished part is not to be ground and polished, the surface may be improved by packing in a neutral material during heating. Soaking should be two to three times as long as the same size and section of carbon tool steel.

**Tempering or Drawing:** The following table gives the approximate hardness values when reheated at various temperatures in deg. F.:

		Hardness	
		Brinell	Rockwell C
As quenched		574	57-58
Tempered at	212° F.	555	57
	300° F.	548	56
	400° F.	530	54
	500° F.	532	53
	600° F.	532	53
	800° F.	512	53
	1000° F.	418	44



## REZISTAL STAINLESS STEEL GRADE B-100

Hardenable Chromium Steel of Group II  
Carbon .90 to 1.10, Chromium 16.00 to 18.00

REZISTAL STAINLESS STEEL, GRADE B-100, because of its higher carbon and chromium content, is a somewhat harder steel than either Grades A or B. Because of its higher chromium content, it is more resistant to corrosion than Grade A. It has found wide application not only

as a superior cutlery steel but also for such applications as ball bearings, bushings, valve parts and other applications where a combination of resistance to corrosion and resistance to wear is desired.

This steel can be hardened to a wide variety of physical properties and hardnesses.

### Fabrication

**Forging:** To forge this grade it should be slowly and uniformly heated to 1950 to 2050°F. To insure slow and uniform heating, it is desirable to preheat at 1450 to 1500°F. Forging should not continue below 1750°F. After forging, the material should be allowed to cool slowly.

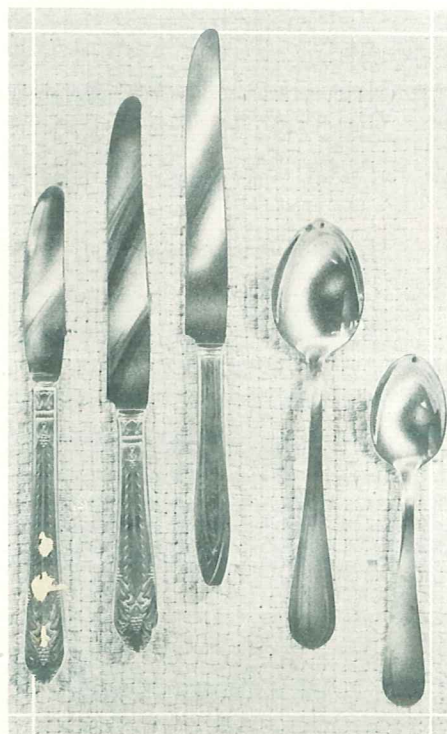
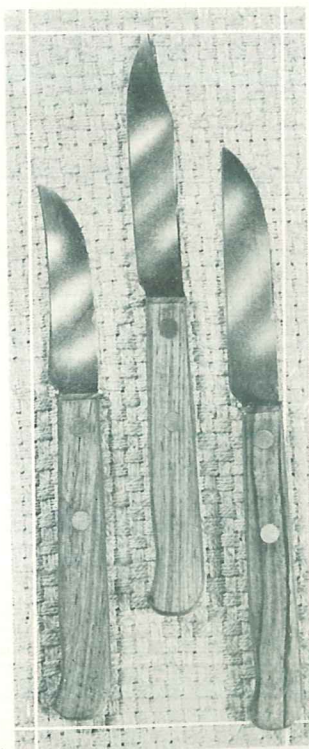
**Annealing:** This grade should be slowly and uniformly heated to 1650°F., held at heat for thorough penetration of the heat and cooled slowly in the furnace.

**Hardening:** This grade should be quenched in either air or oil from 1850 to 1900°F. The steel should preferably be preheated at 1450 to 1500°F. and then brought up to the final quenching temperature of 1850 to 1900°F. It should be held at this quenching temperature sufficient time to assure complete and thorough penetration of the heat.

**Tempering:** The tempering temperature varies with the hardness desired in the finished part. The time at the tempering temperature should be about 2 hours. The following table gives the approximate hardness values when tempered at the various temperatures:

	Hardness Rockwell C
As quenched	60
Tempered at 212°F.	60
400°F.	57
500°F.	55
600°F.	54
700°F.	54
800°F.	55
900°F.	56
1000°F.	52
1100°F.	43

Tempering in the range between 800° and 1100°F. should be avoided, as it places the steel in condition for minimum resistance to corrosion and minimum resistance to impact stress.



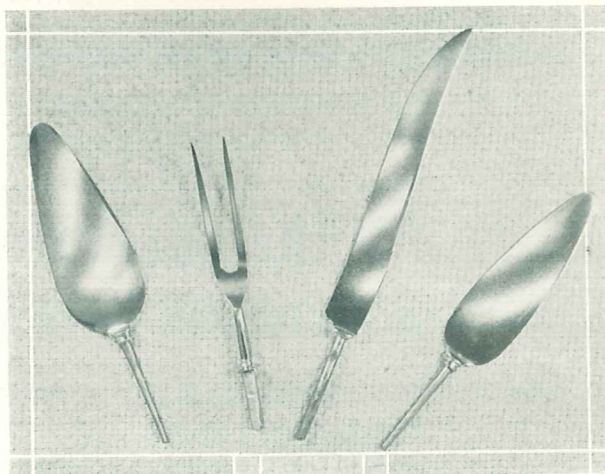


## REZISTAL STAINLESS STEEL GRADE BM

Hardenable Chromium Steel of Group II  
Carbon 1.00 max., Chromium 16.00 to 18.00, Molybdenum about .50

REZISTAL STAINLESS STEEL GRADE BM, is the outstanding stainless steel of the cutlery type. It can be hardened and tempered to maximum hardnesses. It will maintain its cutting edge better than any other type of stainless steel and as a matter of fact is superior to many of the straight carbon cutlery steels. It possesses a valuable free grinding quality which allows the greatest ease in

grinding and polishing obtainable in stainless steels. Its resistance to abrasive wear is superior to that of any other type of stainless steel. All these properties go to make it the outstanding cutlery steel, as well as the outstanding material for a variety of applications requiring one or several of these properties.



### Fabrication

**Forging:** This grade should be heated slowly and uniformly from 2100° to 2150°F., prior to forging. Forging should not continue below 1750°F. After forging the material should be allowed to cool slowly.

**Annealing:** Heat slowly and uniformly to 1650°F. Hold at heat for 5 to 6 hours and cool slowly in the furnace.

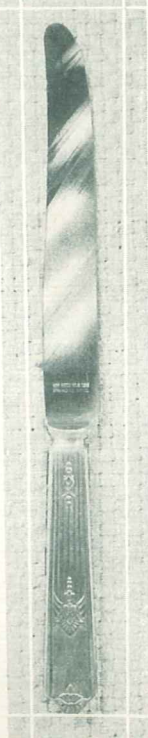
**Hardening:** This grade can be quenched in either air or oil from 1900°F. An oil quench is preferable to an air cool. The material should be preheated at 1450° to 1500°F. before bringing up to the quenching temperature. The steel should be held at the quenching temperature for sufficient time to assure complete penetration of

the heat. The parts should preferably be taken from the oil bath at a temperature of between 450° and 250°F., and immediately tempered.

**Tempering:** This steel is capable of being tempered to a wide variety of hardnesses, as indicated by the following chart:

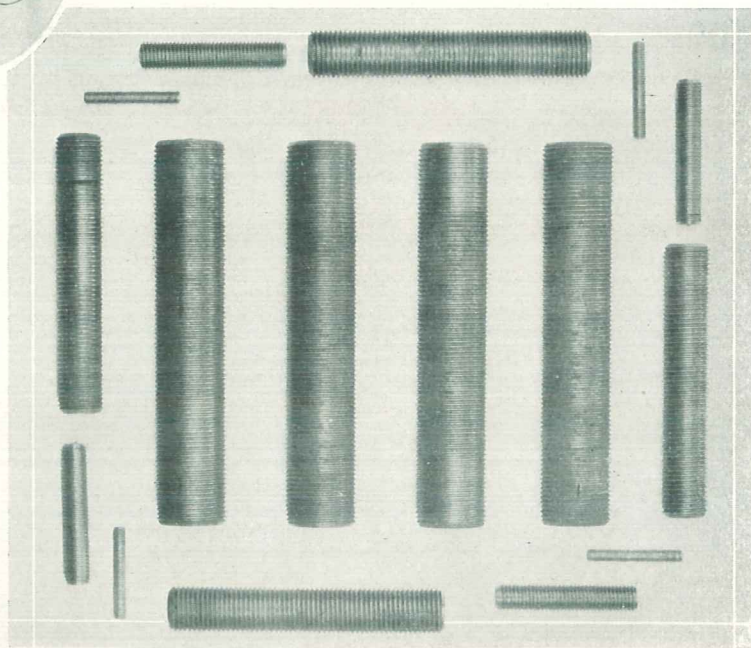
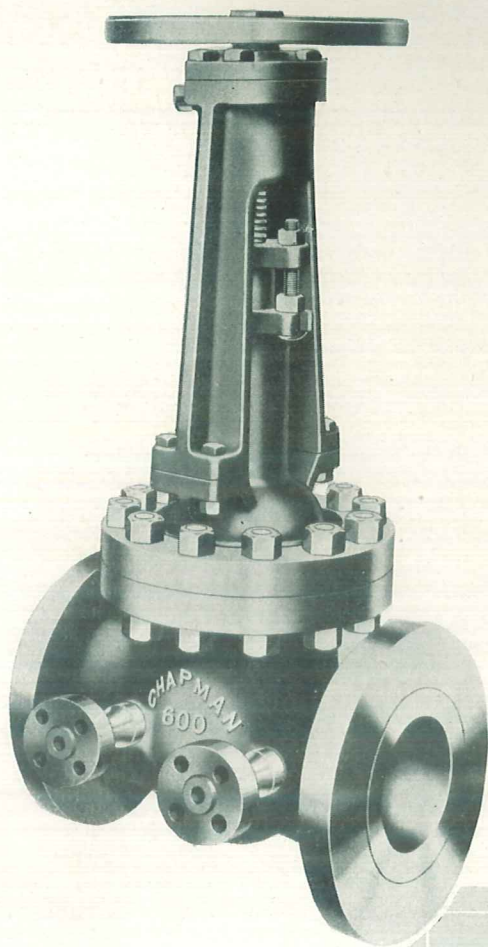
	Hardness Rockwell C
As quenched	60
Tempered at 400°F.	57
600°F.	55
800°F.	55
1000°F.	54
1200°F.	33

Tempering between the range of 800° and 1100°F. should be avoided, as it places the steel in its condition to a minimum resistance to corrosion and minimum resistance to impact stress.





CRUCIBLE STEEL COMPANY OF AMERICA



Valve and Studs made of LO CRO 46 W

## SEMI-CORROSION AND HEAT RESISTING LO CRO 46 STEELS

LO CRO 46 steels are termed "semi-corrosion resisting" because although their resistance to corrosion is not complete for any corroding media it has been found that in certain applications their resistance to corrosion is sufficiently better than that of carbon or low alloy steels to warrant their use. They are therefore, relatively resistant to corrosion in certain media.

LO CRO 46 is frequently alloyed with molybdenum or tungsten. The three most popular steels of this group are:

LO CRO 46	4.00 to 6.00 Chromium	
LO CRO 46 MO	4.00 to 6.00 Chromium	.50 Molybdenum
LO CRO 46 W	4.00 to 6.00 Chromium	1.00 Tungsten

The strength of these steels particularly when molybdenum or tungsten is added is better at temperatures from 800° to 1200°F. than any other of the low alloy steels. This has led to the widespread use of LO CRO 46 MO and LO CRO 46 W for those applications such as headers, studs, bolts, still tubes, etc., that require high

strength and resistance to creep at temperatures between 800° and 1200°F.

When comparative resistance to corrosion only and high strength at elevated temperatures is required one of these steels is generally used. Where strength at elevated temperature is the determining factor either LO CRO 46 MO or LO CRO 46 W are used. LO CRO 46 MO does not suffer a reduction in impact properties after long exposures to temperatures between 800° and 1000°F. and is therefore widely used when operating temperatures in this range are anticipated and where resistance to impact shock is a factor.

As mentioned above the resistance to corrosion of these steels is comparative only and not absolute. The most striking example of this has been the experience of the oil refineries where these steels have been used for still tubes. Although the resistance to corrosion was not absolute, it was found to be 5 to 10 times better than that of ordinary or low-alloy steels thereby more than justifying the additional cost.

### Resistance to Scaling

One of the important characteristics of all of the LO CRO 46 steels is their resistance to scaling and oxidation at elevated temperatures. This can best be shown by the following table which represents the result of tests which called for heating the steels to 1400°F. for 125 hours with an access to air.

From the table it may be readily seen that a considerable increase in resistance to oxidation at high temperatures is obtained with the addition of 4.00 to 6.00 chromium, particularly so when the carbon content is kept low. The resistance to oxidation of LO CRO 46 MO and LO CRO 46 W is slightly less for equivalent carbon content.

	Depth of Scale
.17 Carbon Structural Steel	.0187"
Copper Molybdenum Iron	.0210"
Ingot Iron	.0257"
LO CRO 46 .18 Carbon	.0023"
LO CRO 46 .10 Carbon	.0007"

### Fabrication

**Welding:** LO CRO 46, LO CRO 46 MO and LO CRO 46 W can be welded by either the electric arc or acetylene gas method. These steels are air hardening and the welding heat will cause a hardening at and adjacent to the weld. This air hardening can be removed by a suitable anneal.

There are many applications involving welded LO CRO 46 steels which have not been annealed after welding. It is therefore necessary to analyze the stresses to which the finished part will be subjected and determine whether they are of such a character to require an anneal after welding.



# CRUCIBLE STEEL COMPANY OF AMERICA

## LO CRO 46

Carbon .25 max., Chromium 4.00 to 6.00

This steel comes in a variety of carbon ranges, namely, .10 max., .15 max., .20 max. and .25 max. The lower carbons are slightly more expensive than the higher carbons and are used where ductility is an essential characteristic. A higher resistance to scaling is also obtained with the lower carbons. The higher carbons, such as .25 max., are used for the stud and bolt applications where extreme ductility can be sacrificed for good ductility with additional strength.

These steels may be hardened by either air cooling or oil quenching from 1650°F. They possess splendid deep hardening characteristics and therefore harden all the way through in fairly heavy sections. These steels are capable of being heat treated to a wide range of mechanical properties varying with the carbon content. In the natural condition LO CRO 46 possesses a tensile strength of about 200,000 pounds per sq. in. and has a hardness of about 400 Brinell.

### Mechanical Properties at Elevated Temperatures (short time tests) Previously Cooled in Air from 1300° F.

	Yield Point	Tensile Strength	Elongation in 2"	Reduction in Area
Pulled at room temperature.....	81140	95100	24.0%	73.5%
Pulled at 800°F. after holding for 40 minutes.....	73900	77140	19.0%	76.5%
Pulled at 900°F. after holding for 40 minutes.....	68400	72600	16.0%	73.5%
Pulled at 1000°F. after holding for 40 minutes.....	65400	68300	18.0%	75.1%
Pulled at 1100°F. after holding for 40 minutes.....	59970	62670	19.0%	68.5%
Pulled at 1200°F. after holding for 40 minutes.....	52730	54680	22.0%	85.2%

### Mechanical Properties at Elevated Temperatures (short time tests) Previously Cooled in Furnace from 1575° F.

	Yield Point	Tensile Strength	Elongation in 2"	Reduction in Area
Pulled at room temperature.....	32350	74780	35.0%	75.5%
Pulled at 400°F. after holding for 40 minutes.....	31080	67820	30.0%	77.5%
Pulled at 800°F. after holding for 40 minutes.....	30800	56920	26.0%	75.3%
Pulled at 900°F. after holding for 40 minutes.....	29490	55360	26.0%	73.7%
Pulled at 1000°F. after holding for 40 minutes.....	29070	54600	28.0%	74.8%
Pulled at 1100°F. after holding for 40 minutes.....	23460	45120	32.0%	83.6%
Pulled at 1200°F. after holding for 40 minutes.....	21530	37950	38.0%	88.9%
Pulled at 1300°F. after holding for 40 minutes.....	15850	25870	38.0%	92.7%
Pulled at 1400°F. after holding for 40 minutes.....	15500	20480	39.0%	93.3%
Pulled at 1600°F. after holding for 40 minutes.....	10280	13580	28.0%	94.7%

### Fabrication

**Forging:** Forging on LO CRO 46 should start at 2150° to 2200°F. It should be remembered that this is an air hardening steel and therefore care should be taken to cool the forging slowly, if possible, and to avoid abuse when cold by excessive impact shocks.

**Annealing:** LO CRO 46 can be annealed to its maximum softness of about 140 Brinell by

furnace cooling from 1575°F. A satisfactory softness of about 175 Brinell can be secured by air cooling from 1400°F.

**Hardening:** This steel can be hardened by either air cooling or oil quenching from 1650°F. The desired mechanical properties and hardness can be obtained by a suitable temper.



# CORROSION AND HEAT RESISTING STEELS

## In the Petroleum Industry

CRUCIBLE STEEL COMPANY OF AMERICA first introduced this steel to the Petroleum Industry through the splendid cooperation of the Texas Company and Spang Chalfant Company in 1928. The early experience of the Texas Company in using this steel for still tubes thoroughly demonstrated to them and the Petroleum Industry in general the economy in maintenance cost that could be obtained by the use of a material having greater strength, greater resistance to scaling and greater resistance to corrosion than the ordinary steels formerly used. These properties made it possible to use thinner walled tubing thereby increasing the thermal efficiency of the unit and materially reducing the weight not only of the tubes but of the entire assembly. This early work is considered the outstanding achievement in the use of materials in the Petroleum Industry in the past 15 years. The

signal success of the Texas Company with this material led practically all the major refineries in the industry to adopt LO CRO 46, or one of its modifications, for similar purposes.

The Petroleum Industry during the past 6 years has used many thousands of tons of LO CRO 46 for such applications as still tubes, return bends or headers, heat exchanger tubes, hot oil piping, fractionating column parts and many other applications where comparative resistance to corrosion, freedom from scaling and strength at elevated temperatures are desired. The experience of the oil companies has been, even for those sections beyond the facilities or capacity of the CRUCIBLE STEEL COMPANY OF AMERICA, that maximum safety is assured only when LO CRO 46 billets, as made by CRUCIBLE, are specified on the order to the converter.

## LO CRO 46 MO

Carbon .25 max., Chromium 4.00 to 6.00, Molybdenum .40 to .60

The addition of Molybdenum to LO CRO 46 materially increases its strength at and its resistance to creep at elevated temperatures and reduces the tendency towards temper brittleness after long exposures at 800° to 1000°F. The resistance to corrosion and scaling is not materially affected. LO CRO 46 MO therefore has been used for still tubes and other parts of refinery equipment where greater strength and resistance to creep and freedom from temper brittleness are desired than can be had with LO CRO 46. Its use for studs and bolts on many types of high

temperature problems such as are encountered in the oil refineries, steam power plants, locomotives, etc., is widespread.

LO CRO 46 MO can be obtained in a variety of carbons from .10 max. to .25 max. The lower carbons are generally used for still tubes and other parts where flanges are to be rolled on or expanded or where bending or severe forming is to be done. The higher carbon types are generally used for studs and bolts. LO CRO 46 MO can be heat treated to a wide variety of mechanical properties.

## LO CRO 46 MO .18 carbon

### Mechanical Properties at Elevated Temperatures (short time tests)

Previously Cooled in Air from 1300°F. 167 Brinell

	Tensile Strength	Yield Point	Elongation in 2"	Reduction in Area
Pulled at 800°F. after holding for 40 minutes.....	80000	65000	18.0%	66.0%
Pulled at 900°F. after holding for 40 minutes.....	73000	62000	19.5%	69.5%
Pulled at 1000°F. after holding for 40 minutes.....	69000	63000	20.5%	73.1%
Pulled at 1100°F. after holding for 40 minutes.....	59000	56000	21.5%	79.9%
Pulled at 1200°F. after holding for 40 minutes.....	51000	50000	24.0%	84.5%



# CRUCIBLE STEEL COMPANY OF AMERICA

## LO CRO 46 MO .20 carbon Mechanical Properties at Elevated Temperatures (short time tests) Previously Cooled in Air from 1190°F. 241 Brinell

	Tensile Strength	Yield Point	Prop. Limit	Elongation in 2"	Reduction in Area
Pulled at 800°F. after holding for 40 minutes.....	93800	74000	47300	19.0%	62.5%
Pulled at 1000°F. after holding for 40 minutes.....	77800	62500	41000	22.5%	66.5%
Pulled at 1200°F. after holding for 40 minutes.....	46800	24500	13000	28.5%	80.9%

### Creep Data

Carbon Content	Previous Treatment	Stress to Produce 1% Stretch in 10,000 hrs. Pounds per sq. in.
.20	As Forged and Tempered at 1190°F. to 241 Brinell	at 900°F. 28,000
.19	Heat Treated to 293 Brinell.....	at 1000°F. 9,100
.19	Anneal to 179 Brinell.....	at 1000°F. 8,000

### Fabrication

**Forging:** Should begin at 2150° to 2200°F. and because of its air hardening tendencies cool slowly from the forging temperature and impact blows when cold should be avoided.

**Annealing:** Full softness can be obtained by furnace cooling from 1575°F. However an air cool from 1400°F. will be satisfactory for most applications.

**Hardening and Tempering:** Can be hard-

ened by either air cooling or oil quenching from 1650°F. This is a deep hardening steel and fairly large sections will harden throughout. The desired mechanical properties and hardness can be obtained by tempering at the proper temperature.

**Machining:** Can be readily machined. A Brinell hardness of 175 will produce a crisp chip which renders machining easier than on material that has been annealed to a lower hardness.

## LO CRO 46 W

Carbon .25 max., Chromium 4.00 to 6.00, Tungsten .75 to 1.25

Tungsten when added to LO CRO 46 produces increased strength at elevated temperatures about comparable to that induced by the addition of Molybdenum. LO CRO 46 W is therefore used for those applications where greater strength and resistance to creep at elevated temperatures is re-

quired than is obtainable on LO CRO 46. This grade has been successfully used for still tubes and other parts of refinery equipment as well as for high temperature studs and bolts in the Petroleum Industry, steam power plants and high temperature steam lines.

## LO CRO 46 W .23 carbon Mechanical Properties at Elevated Temperatures (short time tests) Previously Oil Quenched from 1650°F. and Tempered at 1200°F.

	Tensile Strength	Yield Point	Prop. Limit	Elongation in 2"	Reduction in Area
Pulled at 800°F. after holding for 40 minutes.....	103000	90000	62000	18.0%	68.0%
Pulled at 1000°F. after holding for 40 minutes.....	88000	76000	52000	19.5%	75.6%
Pulled at 1200°F. after holding for 40 minutes.....	66800	50380	27500	24.0%	85.0%

# CORROSION AND HEAT RESISTING STEELS

## Creep Data

Carbon Content	Previous Treatment		Stress Required to Produce 1% Stretch in 10,000 hrs. Pounds per sq. in.
.23	1650 °F Oil 1100 Temper.....	{	at 800° F. 43,000
	285 Brinell .....		at 900° F. 23,000
.23	Anneal to 183 Brinell.....		at 1000° F. 8,800
.12	Anneal to 167 Brinell.....		at 1000° F. 8,000
			6,700





# CRUCIBLE STEEL COMPANY OF AMERICA

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